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The Influence Of Orthodontic Treatment On Facial Growth And Development

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Prior to the impact of head measurement with x-ray, the orthodontist was prone to take full credit for all growth change occurring during treatment. All favorable changes were thought to be due to the beneficial influence of his appliances while poor results were often passed off as a result of poor cooperation or failure to carry out instructions. Malocclusion was thought to be primarily the result of pressure habits of many kinds. The whole skull was considered to be subject to vast change and remoulding.

This was the way men thought at the time that Broadbent[1] and Brodie[2] began their early investigations. Little did they realize that their research was to guide or misguide the designs of clinical treatment for years to come. What was it they did and said, and how did it come to be interpreted?

Serial x-ray tracings superimposed over landmarks in the base of the skull suggested that the brain case grew outward in a relatively constant manner. Brodie observed that the lines of the nasal floor and the mandibular border were regular and orderly as one line was parallel to the next. Facial proportions did not seem to change. Is it any wonder therefore that the idea of a constant growth pattern was born? If he said that growth occurred as a constant, the implication was that the same form of the face was maintained only to be repeated on a large scale as growth proceeded.

Read before the Edward H. Angle Society of Orthodontia, Colorado Springs, October, 1959.

In close juxtaposition to that paper another and separate piece of work was produced by the same factory of ideas[3]. This paper served to ignite a controversy of extraction that has flared up at periodic intervals.

Treated orthodontic cases subjected to cephalometric analysis suggested that changes occurred primarily in the alveolar process. The effect of bite opening by rotation of the mandible was noted as intermaxillary elastic traction caused a tipping of the occlusal plane which later tended to correct itself with growth. While not published, these findings led these men to believe that the upper first permanent molar was most difficult to move distally. However, alteration of the maxilla and increased growth of the mandible other than that usually expected was not observed in cases treated by conventional methods at that time.

Consider for a moment what these two incendiary ideas could do to the thinking of the clinician frustrated by failure. On the one hand we had a rather clear cut statement that appliances could not influence growth, which negated everything men had believed and practiced up to that time. On the other hand, there was the implication that things would not get better or worse in time and that the morphogenetic pattern was constant and unchangeable. From this came the revival of the wars between the extractionist and the expansionist which was to overshadow other struggles in dental history.

If the facial bones could not be

changed, was not heredity almost the sole cause of the malocclusions? Why should the orthodontist expend his efforts on mixed dentition treatment only to repeat it when the permanent teeth erupt? If the face could not be influenced and upper molars could not be moved distally, was it not necessary to extract teeth in a large percentage of cases in order to keep the teeth over basal bone?

Forthrightly, many other clinicians in the nonextraction school had cause to doubt the implications made by those early growth and treatment studies. If these assertions were absolutely true would not all early treatment be failure? Was this not a fatalistic approach? Some further explanation was needed for those cases expanded to large and protrusive arches which later were observed to appear much more favorable or normal at adulthood.

Histologic studies suggested that orthopedic forces affected growth at the mandibular condyle. Thus, procedures were recommended and designed to move the mandible out of a "restricted growth confine" of the glenoid fossa. These appliances were to become popular, particularly in Europe.

Some of the researchers said "We never said what you said we said," while the extractionist took this evidence as his brief in the contest with the expansionist. Who was misled? Who was in error? What were the sources of confusion?

In the first place, the treatment paper by Brodie et al. was a preliminary report from the outset. It was a small study (26 cases) and was based on many patients whose prime of growth had long since passed. Also, the oral orthopedic forces employed then varied considerably with those of our present practice. In contrast, any contemporary clinician who today works with cephalometrics to monitor his results, and who treats mixed dentition cases, sufficiently possesses the evidence to refute the concept of gloom regarding the potential of mechanical therapy to produce dental orthopedic changes.

Now let us have another look at the so called "constancy of the pattern". First, constancy does not necessarily imply a straight line or parallel lines of behavior. There can be a mathematical constancy even when things follow a parabolic curve or any other shaped curve. Secondly, Brodie's original work took patients only to the eighth year of life. Yet, inferences have been drawn by many to apply that evidence completely through the adolescent stages of development. Brodie's more recent contribution on late growth did stress variational behavior[4]. Thirdly, a regularity of the pattern did not mean that severe facial convexity at age nine will be just as bad at age sixteen. Brodie never measured this. He sought information about the effects of the eruption of teeth on the growth of the face[5]; however, he did not study mandibular behavior during the transition from mixed to permanent teeth. Finally, is it possible that Brodie was influenced by the constancy of some of the parts of the face he studied to a conclusion of the whole or was the constant average made up from changes in both directions which cancelled out each other? It was evident therefore that better understanding of growth phenomena and treatment effects was desirable. This took the form of morphologic investigations as an effort to determine the differences that exist in human variation as a starting point.

To the morphologic problem, Downs[6] sought to devise a method of describing facial form and denture relationships, subsequently to be called the "Downs' Analysis". Others sought the same goal as witnessed by Bjork's "Face in Profile"[7] and the Wylie "Anteroposterior

Dysplasia" technique[8]. More recently Ricketts[9] described skeletal and denture variation in one thousand clinical cases by employing a simplified form of clinical survey.

With these morphologic studies as a background, clinical and growth investigations in the past ten years have recognized variations in the direction of growth of the chin (Downs[10], Bjork[11], Ricketts[12], Lande[13]). It was noted that the average chin did grow in a direction "almost down the Y Axis". However, this mean was made up of cases growing predominantly in either direction, viz., forward divergent or backward divergent growth of the chin. Moore[14] recently pointed out that irregular variation existed even within the same growing individual.

Probably the most critical analysis of growth and change during treatment was made by Ricketts[15] by employing a combination of laminagraphy of the mandibular joint together with lateral head films. The direction of condylar growth was noted to influence the swing of the chin just opposite to that often described in the literature as the resultant of intermaxillary pull. Whereas upward and *backward* growth of the condyle was usually held to account for forward growth of the chin in the profile, this phenomenon actually contributed to a *downward* movement of the chin or length increase to the profile, viz., obtuse gonial angle. Upward and *forward* condylar growth, when evaluated from the angle of the mandible (acute gonial angle), was noted to be consistent with increase in the posterior facial height and a *forward* growth tendency in the chin. Thus, bite opening in cases with vertical tendencies in the chin compounded the effects of vertical development even in some cases to irreversible open bite. With this knowledge in hand therefore, the growth and behavior of the mandible and its effects on the face were to some measure explainable. Methods of directing mandibular behavior by mechanical manipulation of the teeth were therefore sought[16].

As late as 1953 Bjork[17] summed up cephalometric research and stated that no evidence was presented to lead to the speculation that growth was influenced by treatment. However, Ricketts[18] and Klein[19] speculated that maxillary alteration was caused by extraoral forces. It therefore became difficult to explain all the observed changes in the face during treatment as being due to mandibular growth alone. Changes observed in the convexity of the face were greater than growth could correct even if all mandibular growth was expressed in a forward direction. Thus, better controlled studies of untreated and treated cases were indicated in order to determine the behavior of growth and development with conventional techniques.

The present study was therefore designed to examine the findings of the 1938 paper since those findings no longer appeared wholly applicable. Answers for the following questions were sought: (1) What, if any, is the effect of various current corrective treatment procedures on facial structures? (2) Does similar orthodontic treatment affect all types of morphologic patterns in the same manner? (3) What should be our guides for present orthodontic concepts of growth and treatment?

Material

Growth findings on children with normal occlusion have usually been employed as a control for the study of behavior during orthodontic treatment. Such studies sadly lack strict comparison because the facial patterns that frequently accompany severe malocclusion do not resemble those associated with normal arrangement of the dental

arches. An attempt was made therefore to gather serial or *longitudinal untreated* malocclusion material for the direct comparison with cases orthodontically treated by conventional methods today.

From the observation files of my private practice two untreated groups of patients were selected for longitudinal study. The first group of fifty averaged age 8.1 years and was a Class I malocclusion selection. Nineteen possessed good occlusion, twenty-two were bimaxillary dental protrusion cases and the other nine displayed varieties of Class I orthodontic problems. Five cases were extracted serially but no orthopedic correction was employed.

The second group was fifty selected Class II malocclusion cases also averaging age 8.1 years. This group contained twenty-four Class II, Division 1 and twenty-six Class II, Division 2 cases. An attempt was made to select cases nearly as possible of an age and sex group and span of time consistent with that usually experienced in treatment, particularly with headgears.

It is well known that Class II malocclusion cases are corrected clinically by many different treatment techniques. A knowledge of the differences in the results of some of these techniques was desired in this study. Therefore, three groups of treated patients were selected for a comparison with the non-treated and with each other. The third sample of fifty cases was treated by extraoral anchorage, primarily the Kloehn type, as the only source of correction of the Class II. The fourth group, a treated Class II sample, was selected on the basis of intraoral traction or intermaxillary elastics employed alone. The final and fifth group was chosen from cases treated by a combination of an assortment of extraoral and intraoral traction. Careful anchorage preparation or anchorage conservation according to my own practice was employed in many of the latter group.

With the exception of thirty-two Class II cases treated only with intermaxillary elastics which were traced from records of the University of Illinois, all the remaining cases were private treatment cases from my practice.

In the group in which the Class II was corrected with headgear alone, extraction was employed in only four cases. In both the intermaxillary elastic group and the combination group fifteen cases had extractions in the upper arch. Lower extraction was involved in eleven and twelve cases in those groups respectively.

The age groups with other data are seen in Table I. As would be expected the latter two samples were slightly older than the control or headgear samples. However, the time interval is very similar in most groups. Only three months difference was seen in the Class II headgear-treated group compared with the controls. Often the x-rays of treated samples were taken the same day that appliances were removed; however, x-rays in a few cases were not obtained until some weeks later.

Each group was divided into Class II, Division 1 and Class II, Division 2 malocclusions and studied separately. Further subdivisions were made into facial types. Selections for this classification were made from one standard deviation from the mean of one thousand clinical cases in a combination of the X Y axis, facial and mandibular plane angles as described by Ricketts[9]. Those with prognathic tendencies (chins upward and forward) were distinguished from those with retrognathic tendencies (chins downward and backward)*. Behavior was then studied in each category separately.

TABLE I

SAMPLE GROUPINGS

50 Cases each	Ave. Age	Duration mos.	Sex F	Sex M
Class I Nontreated Retro (11 cases) Pro (22 cases)	8.1	30	29	21
Class II Nontreated Div. 1 (24 cases) Div. 2 (26 cases) Retro (19 cases) Pro (18 cases)	8.1	30	28	22
Class II Headgear (Neck Strap) Div. 1 (36 cases) Div. 2 (10 cases) Class I (4 cases) Retro (13 cases) Pro (17 cases)	8.8	27	28	22
Class II Intermaxillary Div. 1 (29 cases) Div. 2 (21 cases) Retro (15 cases) Pro (12 cases)	11.7	30	30	20
Class II Headgear and Elastics Div. 1 (36 cases) Div. 2 (14 cases) Retro (12 cases) Pro (14 cases)	11.0	34	28	22

Method

Measurements were made from tracings of lateral serial cephalometric head films (Fig. 1). An effort was made to study the cranial base, mandible, maxilla, teeth and soft tissue profile of the nose. Planes, angles and landmarks employed were as follows:

Cranial Base (upper face) — N-S-Ba, S-N growth, S-Ba growth.

Mandible (lower face) — facial angle, X Y axis angle, the intersection of the Y axis with basion-nasion, mand. plane angle, N-S-Gn, S-N-Pog, condyle axis angle.

Maxilla (middle face) — Point A to facial plane, S-N-A, S-N-Ans, S-N-Ans-Pns (palatal plane).

Teeth — S-N-$\underline{1}$, $\underline{1}$ to APo, $\overline{1}$ to APo, $\overline{1}$ to symphysis, occlusal plane to mand. plane, mandibular plane to $\overline{6}$ ^> PTM to $\underline{6}$ <

Nose — Ans to nose

Each figure, when necessary, was reduced to yearly increments by dividing the total figure by the time involved. All serial measurements were measured and averaged rather than taking

*Retrognathic cases possess facial angles 82° or less with X Y axis 0° or less. Mandibular planes are usually high in such cases. Prognathic cases possess facial angles 88° or more and X Y axis + 6° or more. Mandibular planes are low in these but not necessarily so, as in severe Class III.

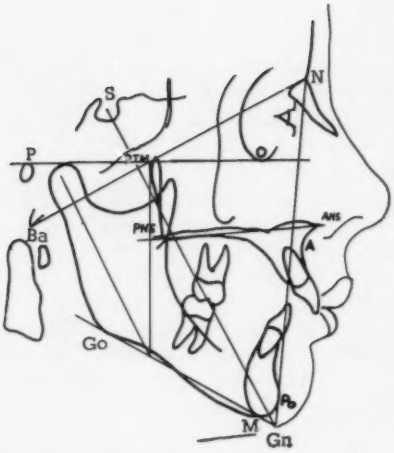

Fig. 1. A typical tracing of a lateral headfilm with landmarks and points selected for study. Lines drawn are the Frankfort plane, selected from the top of the ear canal to orbitale, the facial plane from nasion to pogonion, the Y axis from sella to gnathion and the mandibular plane from gonion to gnathion. A perpendicular was dropped from the posterior margin of the pterygopalatine fossa to the mandibular plane from whence a line was drawn to the center of the condyle; this represented the *condyle axis for* measuring changes in posterior height.

the difference between the means. Standard deviations and standard errors were made where interest seemed to warrant further analysis for our immediate purpose. Due to the amount of material involved, the first considerations were those of gross factors or gross differences to be found as leads to a more critical handling of the data.

Cranial Base

The changes in the angle formed by nasion-sella-basion together with the increases in these planes were measured. The averages of this angle at the start of the observation periods were found to be almost identical in the different groups, averaging 129.7. Extreme variation from a low of 114 degrees to a high of 142 was noted. The standard deviation was 4.8° at the start. The mean change in the angulation of the cranial base was zero, the standard deviation was 1.3 and standard error .12 in the 100 nontreated cases. Cases were observed to increase as much as four degrees or decrease as much as five degrees in the time studied (Figs. 2 and 3).

As would be expected, the sella-nasion line was slightly longer at the start of records in the older age groups. The average in the mixed dentition cases at age eight was about 68 mm and the average-age-eleven cases were slightly more at 71 mm in length. During the observation period the SN line increased in yearly increments of .86 mm per year although extremes were noted in this dimension. The S. D. was

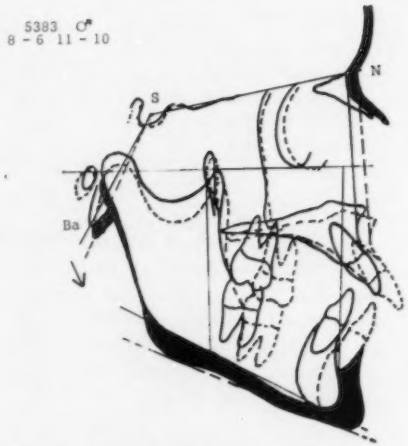

Fig. 2. Growth in an untreated Class II, Division 1. Superimposition is on SN registered at S. Note the downward and forward movement of basion and the downward movement of the condyle. This was consistent in this patient with a forward movement of the chin. The upper incisor erupted forward to a more protrusive position which was typical of untreated Class II, Division 1. The angle SNA remained constant as point A grew forward at an identical rate with nasion. This was typical of untreated cases, both Class I and Class II.

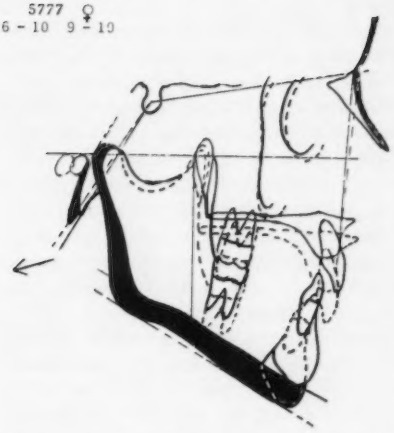

Fig. 3. This shows the development of a retrognathic pattern and a case that developed a deep bite Class II, Division 2 malocclusion. Note the downward and backward movement of basion and the backward movement of the condyle together with basion. The mandibular plane angle increased and the angle SNA decreased. The upper incisor in this case moved slightly posteriorly; this was rare growth behavior in the one hundred untreated cases studied.

0.3 and S. E. .0012. Some patients, especially girls after age twelve, appeared to be dormant in the cranial base. Other cases, especially some boys at puberty, were observed to increase on SN as much as 2.5 mm per year. Bjork has discussed the mechanism of growth in this line.[20] He showed that after age eight the increase was due to growth at the frontonasal area rather than the cranial vault.

The same range of growth variation was noted in the line sella-basion. This dimension, however, was slightly less averaging in the five groups 0.7 mm. per year. The length of the sella-basion line in the eight year old samples was about 43 mm and in the older group around 45 mm. Surprisingly enough, the sella-basion dimension was observed to increase at a greater rate than the sella-nasion dimension in some cases possibly due to activity at the spheno-occipital synchondrosis (see finding on Class I controls).

Essentially no correlations could be determined relative to the cranial base configuration with that of the face with one exception. Long retrognathic patterns tended to be consistent with more acute cranial base angles (129°) than square faces with prognathic tendencies (131°); however, the variation overlapped extensively. This would slightly suggest that a bend in cranial base relationship was related to the length increase in the face. This has also been studied by Lindegard[21].

It can be summarized on the basis of two hundred and fifty cases that the cranial base angle has a strong tendency to remain the same, that the sella-nasion line increases generally at the rate of almost 1 mm per year and that the sella-basion increase is about three-fourths of that amount. Age and sex show variables. Certain important considerations of cranial references will be noted in Figures 2, 3 and 4.

Mandible

When the data showed that several different cranial references yielded similar results, we concentrated on those which we felt were most suited for our purpose. Thus, the gross findings on SNPog, N-S-Gn and SNGn are included; however the changes in the facial angle, the X Y axis and the mandibular plane were studied in detail. The condyle axis change to basion-nasion also was investigated (Fig. 1).

The facial angle, selected as a depth indicator, was noted in the one thousand clinical cases to be 85.4°. The top of the ear canal was used as porion rather than the machine ear post. In the present samples, the average was 86.1 in the Class I, 84.0 in the non-treated Class II sample, 85.0 in the headgear sample, 84.7 in the inter-

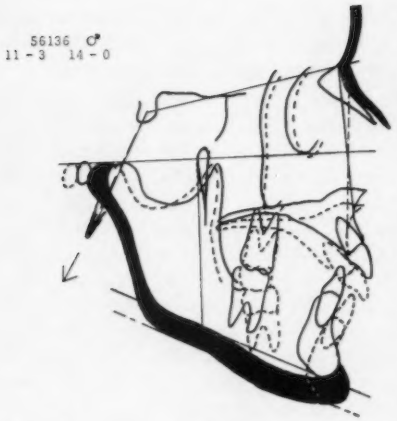

Fig. 4. Representation of a Class II, Division 1 case that was found difficult to treat. Basion moved downward and backward but the condyle and, apparently, the fossa moved straight backward along the Frankfort plane. The mandibular plane increased slightly although there was good growth of the mandible. In this instance the SNA angle was decreased almost eight degrees and the upper incisor torqued lingually. The malocclusion might have been easier to treat had the condyle and mandible not moved so far posteriorly.

maxillary sample and 86.0 in the combination treatment sample at the start of records.

Without treatment, the facial angle improved 1.2° and 0.8° respectively in the observation groups in thirty months i.e., 0.35° per year (Fig. 2). In the headgear sample, the increase averaged less at only 0.5°, i.e., 0.2° per year. This characteristic was essentially the same for patients treated with intraoral anchorage alone, the average increase there being 0.7°. However, in the patients treated with combination anchorage, the improvement was slightly more than observed in either of the other three samples. It increased 1.3°.

These samples were also broken down into retrognathic and prognathic tendencies and were studied accordingly. All four Class II samples of the retrognathic cases collectively averaged about 82.5°. The prognathic tendencies samples averaged about 87.5°. Slight differences were noted in the comparison of nontreated samples with the extraoral anchorage sample as the mandible came forward at a slower pace with treatment. Larger differences were apparent in the compound anchorage sample in which the facial angle showed much greater improvement in the prognathic type cases. However, the greatest change observed was in the combination sample in which almost a 2° change was noted in the retrognathic sample. The mean changed from 83.4 to 85.3 which was thought to be an outstanding finding. Figure 5 shows the facial angle in a case followed for three years with no treatment and then treated in two years. A radical difference in behavior was noted at the time of treatment.

Summarizing these tendencies, the facial angle suggested similar facial depth in all the samples at the start for the age groups and classifications. Improvements in the facial angle appeared to be slightly inhibited by the cervical headgear but improved with high pull headgear and conservative anchorage of the lower arch. The findings and conclusion of the facial angle behavior could be similar to the findings SNB of other cephalometric systems but are not directly comparable.

Of great interest was the amount of growth on the Y axis or SGn. Increases in the SGn line were as follows: 8.0 mm in the Class I control, 7.2 mm in the Class II control, 7.6 in the headgear cases, 6.5 in the elastic traction cases and 8.2 in the combination sample. Reduced to yearly increases on the Y axis, increments in the groups were 3.2 mm, 3.1, 3.4, 2.6 and 3.0 mm. Smaller increase in the intermaxillary elastic sample could be explained because of the higher number of girls

at puberty in that sample. Thus, no great difference was observed in the amount of increase in the nontreated with patients treated in any of the methods employed for this study. It should be pointed out however that these measurements are not direct mandibular comparisons. (Note posterior condyle movement in Fig. 4).

In the Class II group without treatment, the X Y axis angle opened slightly -0.26° (Fig.3). In those cases treated with either the neck strap or intermaxillary elastics, the X Y axis was opened more at -1.0° average. No mean difference could be seen in the behavior of different patterns treated with headgear; they all tended to be opened with the neckstrap. Great differences were observed in those cases treated with intermaxillary elastics only and who possessed retrognathic patterns (Fig. 6); these opened an average of almost 2°. Prognathic types tended to resist bite opening by rotation of the mandible, therefore the bite was corrected by depression of teeth (Fig. 7). In the cases treated with a combination of anchorage, the X Y axis angle was noted to change about the same as in the control, i.e., opening only slightly at 0.3°. With patients treated

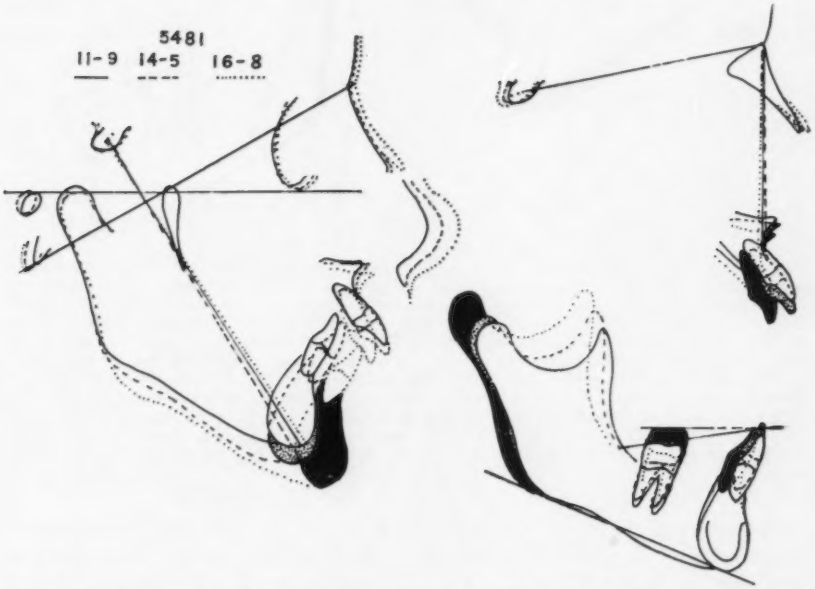

Fig. 5. Serial tracings of a Class II, Division 1 malocclusion observed for almost three years and then treated with a combination of cervical and high pull headgears directed at the molars. While under observation no improvement in the occlusion was noted. Notice that the Y axis first opened with no treatment employed, yet, with treatment by conservative anchorage and four bicuspid extractions, the chin grew forward. Note the difference in the amount of condylar growth between the ages eleven years, nine months and fourteen years, five months with that of the growth experienced between fourteen years, five months and sixteen years, eight months. The growth seen in this patient was not attributed to treatment because the boy did not mature physically during the observation period but did spurt in growth after fourteen years, five months. There was a slight posterior movement of the upper incisors together with a slight modification of point A as can be seen in the upper right illustration. Note the favorable behavior of the lower arch.

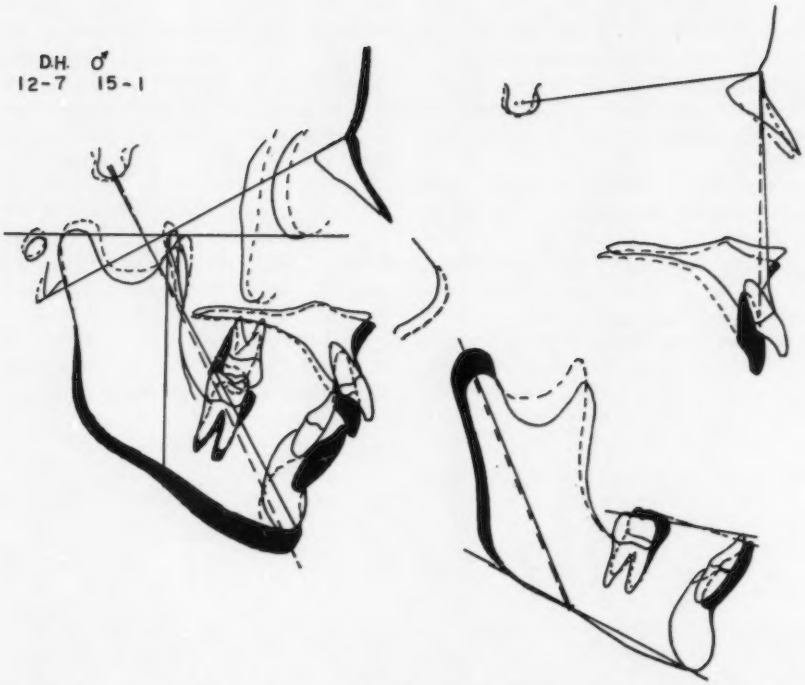

Fig. 6. A retrognathic pattern treated with second order bends and intermaxillary elastics only. Notice the drop in the mandible with an increase in the mandibular plane angle; the convexity of the face was not improved despite a slight improvement in the SNA angle. There was some downward and backward movement of the upper first molars, primarily by tilting of the entire occlusal plane. Note the upper and forward movement of the lower first molar, the forward movement of the lower incisor and the tilt of the occlusal plane on the mandible. The teeth were thrown against the labial musculature and later slightly relapsed. The convexity of the face was not improved. Compare this case with Fig. 15 which was a similar malocclusion treated with extraction of four bicuspids and in slightly less than one year. This patient did not grow commensurate with many boys treated at the twelve-thirteen age level as treatment produced a downward and backward rotation of the mandible.

with high pull headgear the Y axis was improved in some otherwise expected to get worse (Fig. 8).

In summary it can be stated that cervical anchorage and intermaxillary elastics tend to open the X Y axis or lengthen the face much faster than usually observed with normal growth. However, this is thought to be due to bite opening since differences in the length of the Y Axis were not observed. Backward rotation of the mandible is seen more in retrognathic patterns. The tendency to open is greatest in retrognathic cases treated with elastics; prognathic patterns tend to remain constant or improve except in cases treated only with the neck strap. Age and sex differences were apparent; boys in general had more growth except at pubertal differences.

The mandibular plane angle average of one thousand cases was 25.6°. This was measured from a Frankfort plane

employing the superior aspect of the auditory canal rather than the machine porion. The present samples were as follows: Class I control 25.7°, Class II control 27.7°, headgear 25.6°, intraoral anchorage sample 24.1° and multiple anchorage sample 23.3°. Facial types selected from the facial angle and Y axis readings showed retrognathic faces to have an average mandibular plane of 29.2° for the latter four groups. A mean of 20.9° was observed in the prognathic type faces.

In both the control samples the mandibular plane showed a slight tendency to decrease -0.5° and -.6° but in isolated cases, it increased. The decrease was especially noted in the prognathic type cases (Fig. 7). Cases treated with cervical headgear, however, increased an average of +.5°, again, retrognathic patterns paced this change. The same behavior pattern was portrayed in the children treated with intermaxillary elastics. However, the combination sample decreased even more than the control and this included the retrognathic sample which decreased -1.0°.

In summary, it can be said that the mandibular plane showed similar characteristics to the X Y axis in behavior during growth and treatment, i.e., when the chin dropped downward, the mandibular plane increased. Low mandibular angles tended to become lower while high angles tended to remain so or increase. The improvement

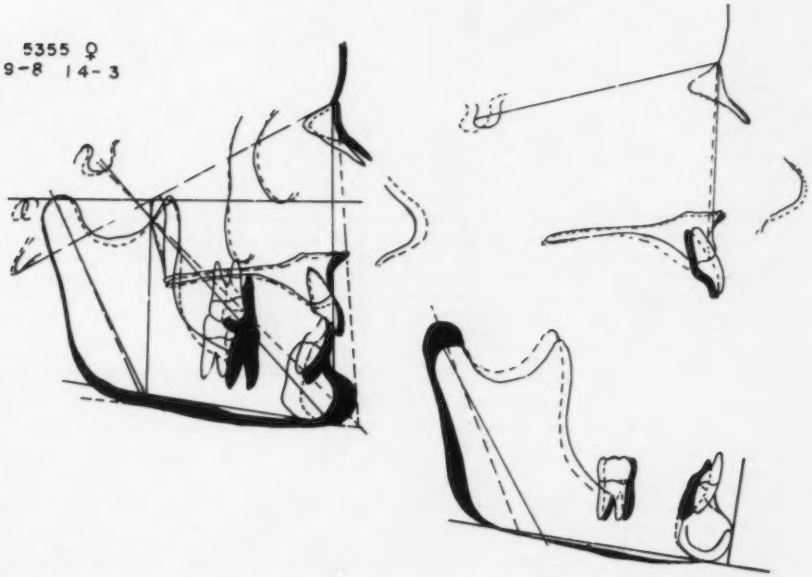

Fig. 7. Behavior in a treated Class II, Division 2 with prognathic and brachycephalic tendencies with deep overbite and spacing in both arches. This case was also treated solely with intermaxillary elastics but in contrast with Fig. 6 the chin grew forward and the mandibular plane angle decreased. In this youngster the condyle grew upward and forward consistent with forward growth of the chin. In the treatment of the closed bite condition the lower incisors were actually intruded into the bone rather than increasing the anterior facial height by rotation of the mandible downward and backward as seen in Figs. 6 and 15. The Y axis closed almost five degrees.

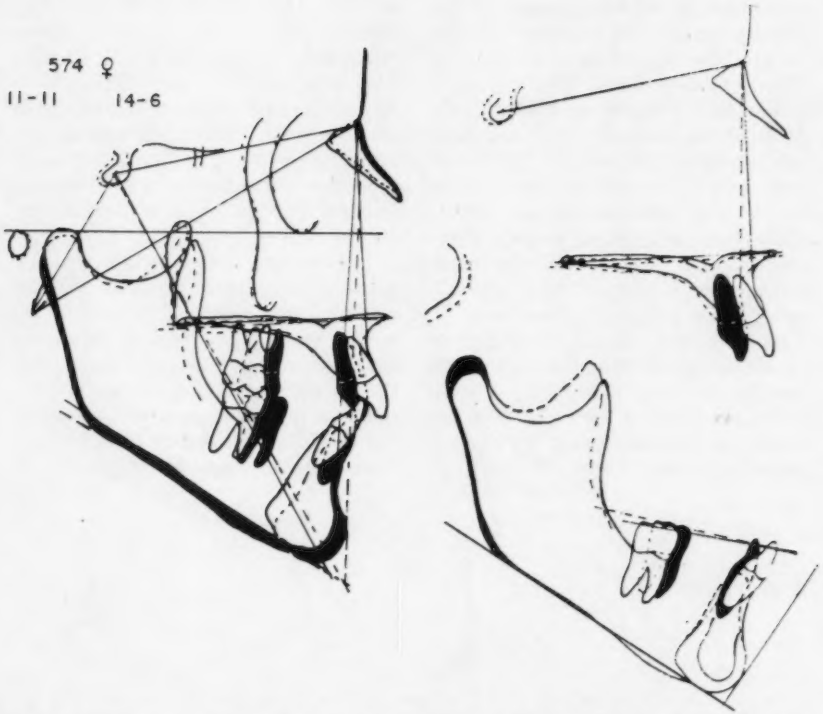

Fig. 8. Tracings of a girl with a Class II, Division 1 in a mesognathic facial pattern with a high mandibular plane angle. She was treated with a high pull headgear on the anterior teeth and four bicuspid extractions. This patient showed several millimeters of gingiva when she smiled; this condition was improved with treatment. Note the stability of the occlusal plane and the direct posterior movement of the upper incisor. A rather average amount of growth for a girl aged twelve is demonstrated here.

in some of the retrognathic cases treated with high pull headgear and anchorage conservation was a surprising finding (Figs. 5 and 8).

The condyle axis was established by dropping a perpendicular from Frankfort plane through the most posterior curvature of the pterygopalatine fossa to a point intersecting the mandibular plane on the mandible. From this point a line was erected to the center of the head of the condyle by inspection and the change in this plane was studied.

Growth of the condyle on this axis was previously reported by Ricketts[12]. The growth averaged 2 mm per year and variations in amount and direction were noted. In these samples the angular change from basion-nasion plane was found to open slightly with treatment. In the controls it opened slightly, 0.8° and 0.4° respectively. However, it opened 0.9°, 1.0° and 1.3° in the other samples which would be expected with bite opening. The tendency for greater opening in retrognathic patterns was again noted.

In summary, bite opening or posterior growth (ramus height) tended to open the condyle axis to basion-

nasion although a wide variation was noted. Anterior growth of the condyle tended to be consistent with deep facial growth (Fig. 7), while posterior growth tended to be correlated with length increase to the face and long shallow faces (Fig. 9).

Maxilla

Two factors are of interest in the study of relationship of the middle face. One is the maxillary relationship to the profile or facial plane and the other is its relationship to cranial references.

For profile study point A was taken directly to the facial plane as a measure of facial contour (Fig. 11). This figure averaged 4.7 mm in the one thousand clinical cases although Downs' normals revealed a mean of 0 mm. In our cross-sectional study of one thousand cases

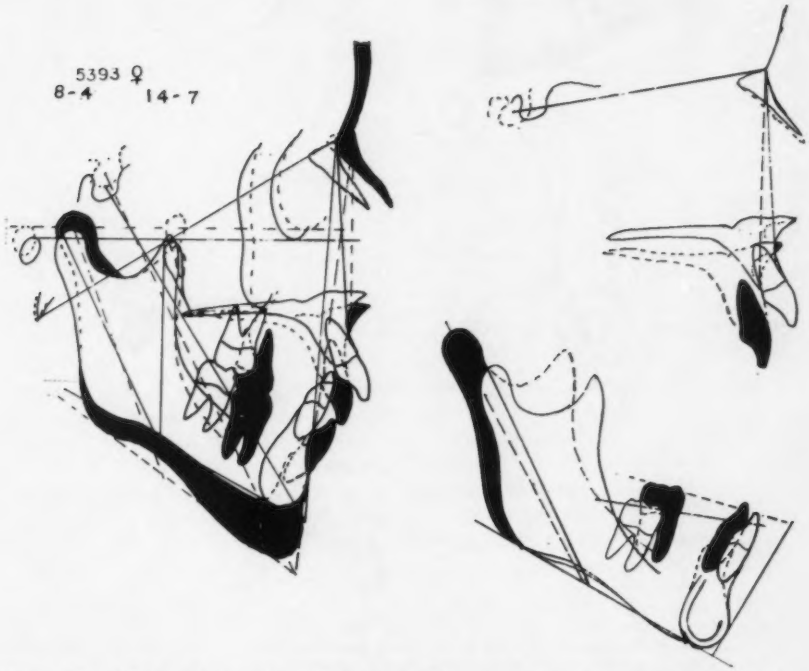

Fig. 9. Tracings of a girl started at age eight and treated with a cervical headgear. Actual decrease in depth of the face and tremendous height development in the face was found. The Y axis opened about six degrees and the mandibular plane angle increased greatly. The second stage of treatment included four bicuspid extractions with high pull headgear and Class III anchorage preparation; in spite of this treatment designed to prevent height increase lengthening of the face continued.

This girl grew more than a foot in height from eight to fourteen years and was still growing at her last appointment. After treatment the patient is now showing a tendency for open bite. Note the lower incisor appears to be more forward in the tracing on the left in spite of the fact that it was retracted almost its full width to the symphysis as seen on the tracing on the right. The occlusal plane tilted upward and forward, downward and backward movement of the upper incisor and the entire palate was experienced during treatment. The predominant upward and backward growth of the condyle is consistent with the vertical increase in facial height.

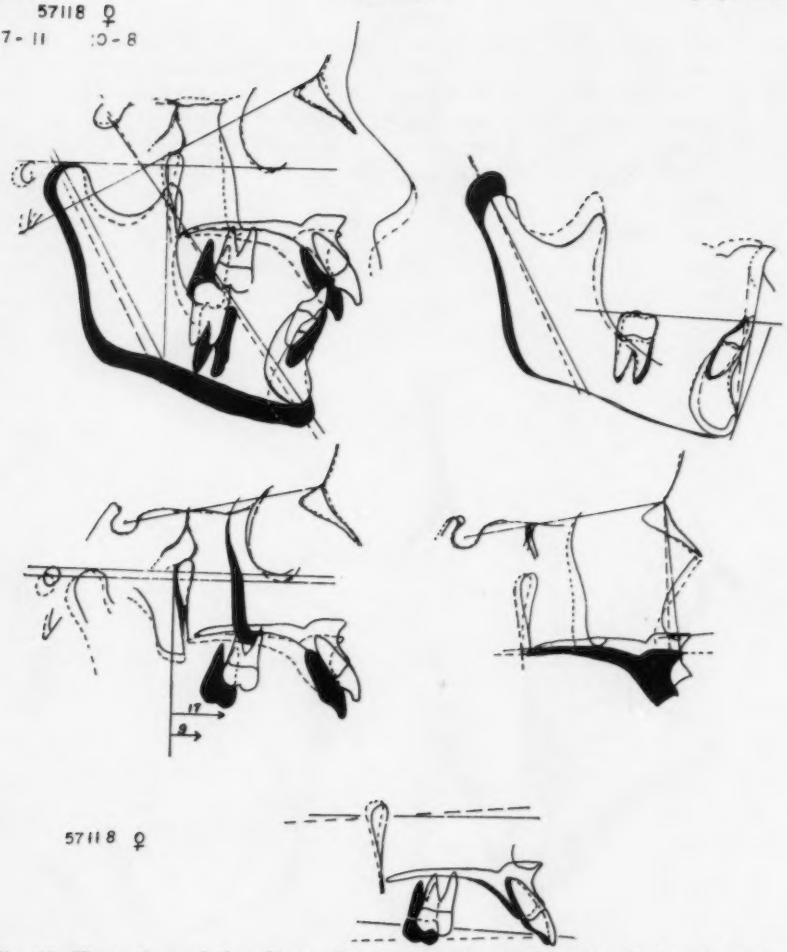

Fig. 10. Illustrations of the effects of extraoral anchorage in a closed bite with strong mesognathic pattern. Downward and backward movement of the mandible can be seen; the downward and backward movement of the upper first molar was almost the full width of itself. Note the lower first molar was slightly depressed as the occlusal plane slightly decreased during treatment. Note what might be an alteration of the key ridge and possibly the pterygomaxillary fissure. The growth behavior of the condyle was favorable.
This girl was treated with a combination of cervical anchorage and high pull headgear directed at the upper first molars. She also had a buccal crossbite of an upper first molar in addition to a severe Class II, Division 1. Originally the upper molar was seventeen millimeters from a perpendicular to the Frankfort plane at the posterior margin of the pterygomaxillary fissure; after treatment this dimension was only nine millimeters. The palatal plane, point A and the anterior nasal spine were moved downward and posteriorly during treatment. Untreated cases with this facial pattern showed that point A usually continued to grow forward. The bottom figure illustrates a downward and backward movement of the upper molar when only the midsagittal landmarks of the palate are superposed. Notice the elongation of the upper first molar and the lingual movement of the upper incisor which was banded in the final phases of the first stage of treatment and then experienced lingual root torque.

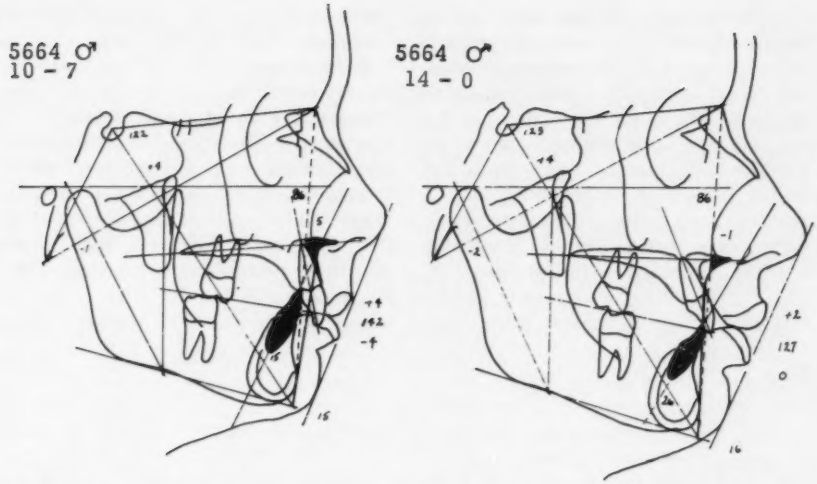

Fig. 11. Before and after treatment tracings of a severe Class II, Division 1 closed bite case with a mesognathic pattern and moderate facial convexity. This patient was treated by a combination of cervical and high pull headgear. After treatment there is actual concavity to the profile as the A-pogonion plane has been brought backward over the lower incisor. Originally the lower incisor was four mm lingually to this plane and situated at an inclination of fifteen degrees. Following the retraction of point A and forward growth of the mandible, the lower incisor is now in a good reciprocal relationship to the upper and lower jaws which finds it exactly on the A-pogonion plane tilted forward twenty-six degrees. More uprighting of these teeth will be found during further growth.

decreases of approximately 1 mm for every four years age difference were noted. Youngsters three to six years averaged +5.5 mm while cases decreased until age fifteen to eighteen in which the average was only +2.5 mm in facial convexity.

A similar finding was observed in the present longitudinal sample of untreated cases. In the Class I control a mean of only 2.7 mm of convexity was noted. A mean of 4.5 was found in the Class II control. Both decreased about .5 mm in the thirty months observed (Fig. 2). However, some did not improve (Fig. 3). The headgear cases at a similar age averaged 5.8 mm convexity before treatment. Convexity at the end of treatment was only 2.7 mm, thus reduced 3.1 mm by the headgear and growth (Fig. 10). Retrognathic cases were almost 8 mm in convexity and reduced an average of about 4 mm during treatment.

Cases treated by elastics averaged only 4.0 mm in convexity at the start but only 1.2 mm decrease in convexity was observed (Fig. 6). Facial patterns made little difference. Extraction cases treated with continuous force and lingual root torque on the upper incisors were noted to change by depression of the subnasal area at point A. The change in convexity patternwise was essentially the same during intermaxillary elastic treatment in spite of the fact that retrognathic patterns averaged 6.2 mm at start and were reduced to 4.9, and prognathic patterns were 1.8 and reduced to 0.5.

The greatest change occurred in the multiple anchorage cases. Starting out with a convexity of 5.1 mm they measured 1.3 at the end of treatment.

This represents a 3.8 mm reduction in the profile on the average. In retrognathic patterns in this sample point A was found essentially 7 mm anterior to the facial plane and was reduced to 2.4 mm, a figure approaching 5 mm as an average reduction in point A in the profile (Fig. 12). A reduction of 3.2 mm was even found in the prognathic cases. Some of these cases finished with a slight concavity to the profile (Fig. 11). *This finding of convexity reduction is strikingly significant when compared to the controls which displayed very little change in convexity.*

Sella-nasion to point A has come to be employed as a reference line in treatment planning and analysis of treatment by Steiner[22]. Lande's studies and Brodie's early investigation both showed a remarkable constancy of this angle. Other studies have suggested that this angle increased slightly in growth in normal facial patterns. This is corroborated in the Class I series which showed a +.5° increase in a

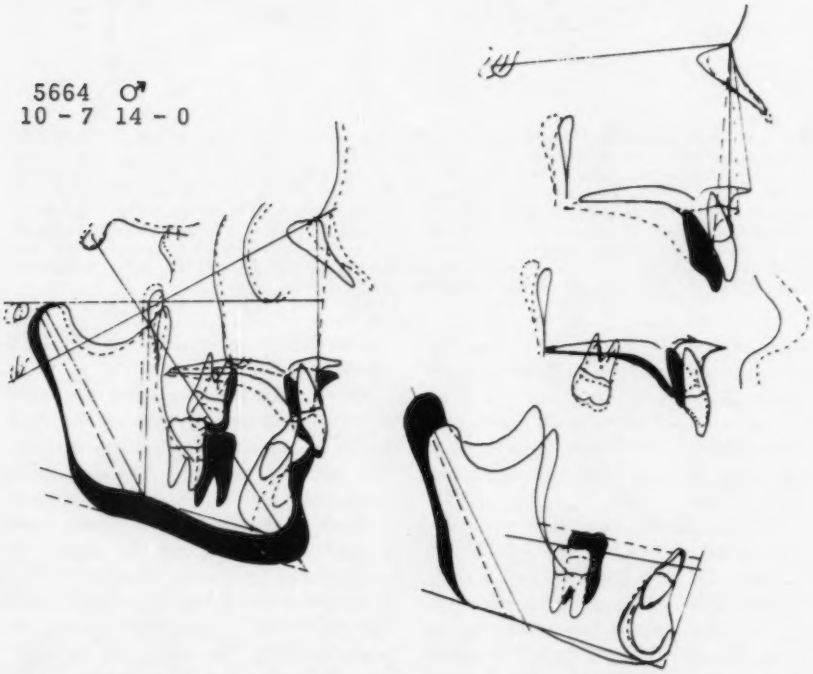

Fig. 12. An analysis of growth and treatment of the case shown in Fig 11. Notice on the left that good growth was experienced and treatment took advantage of the vertical development of the mandible without any increase in the mandibular plane and without unnecessary depression of the lower incisors. Note that point A, the anterior nasal spine and the upper incisor and what appears to be the entire palate were tipped downward and backward during treatment. The upper incisor root was moved upward and posteriorly with torque. At one stage of treatment an x-ray indicated the upper incisor root tip to be into the floor of the nose. Keeping in mind that the normal case exhibits a downward and forward movement of point A and the upper incisor, the assessment of effective change of the upper incisor must be made from the position that it would have taken had treatment not been employed.

thirty month interval. The Class II control sample demonstrated an average increase of +.3° in the observation period, increasing from 79.6 to 80.1. S-N-anterior nasal spine was also tested to the same general finding, however, its forward tendency was slightly greater at .6° in both control samples. Both control samples combined thus yielded a mean SNA change of +0.4° with a S.D. of ±1.3°.

In all three treated samples the behavior of point A and the anterior nasal spine was reversed from the normal growth tendency as point A moved backward with treatment. SNA was reduced an average of 2.7° with the headgear alone and only .9° (Fig. 8) with elastics — a three to one ratio in effectiveness. The combination sample decreased an average of 3.1° (Figs. 3 and 11).

The average SNA angle in the Class I sample was 80.6 and the observation Class II sample yielded a mean of 79.6 at the beginning. The headgear sample mean was 82.5 while that of the combination sample was 82.7. Class II, Division 1 cases were noted to average 82.0 at the start of treatment.

The anterior nasal spine in the treated cases showed the same behavior but to a slightly less degree. Almost 2° reduction was noted on the average in cases treated with both forms of anchorage.

Brodie's findings also emphasized that the palatal plane (ANS-PNS to SN) tended to remain constant but, if anything, lowered slightly in the anterior area. This also was corroborated in the control samples wherein the Class I average was 0 and an increase of 0.2° was observed in the Class II nontreated (from 7.6° to 7.8°) (Fig. 2).

In the treated cases this was accentuated. The downward tipping averaged 1.6° in the headgear cases (Fig. 10) and 1.3° in the combination anchorage case (Fig. 11).

In summary, the convexity of the face tended to improve slightly with growth and was improved additionally with treatment by intermaxillary elastics. However, much greater convexity change was noted when extraoral anchorage was employed and the greatest change occurred in the combination anchorage cases. Under normal circumstances point A and the palatal plane tended to remain constant to SN but if anything point A moved forward slightly. Under treatment with only intermaxillary elastics point A and the palatal plane changed but little. However, great changes in point A in a downward and backward direction were noted in cases treated with cervical headgear (Figs. 9 and 10). In cases treated with headgear and conservative Class II intraoral anchorage the changes were greatest in movement of point A posteriorly and not quite as much tipping of the palatal plane was noted. For patients treated by high pull headgear on the anterior area the palatal plane was not tipped downward to the same degree as those treated by cervical anchorage (Fig. 8).

Teeth

The point A pogonion plane has been employed as a reciprocal reference to describe teeth relative to the most anterior basal bony landmarks on the jaws. It was observed that pogonion generally moved forward with growth and that point A generally moved backward with treatment, so a measure of the incisor tips to this plane described only the relationship before and after and was not taken to represent tooth movement during treatment. The outline of the maxilla could no longer be accepted as a reference for maxillary tooth movement because both point A and the palatal plane appeared to be

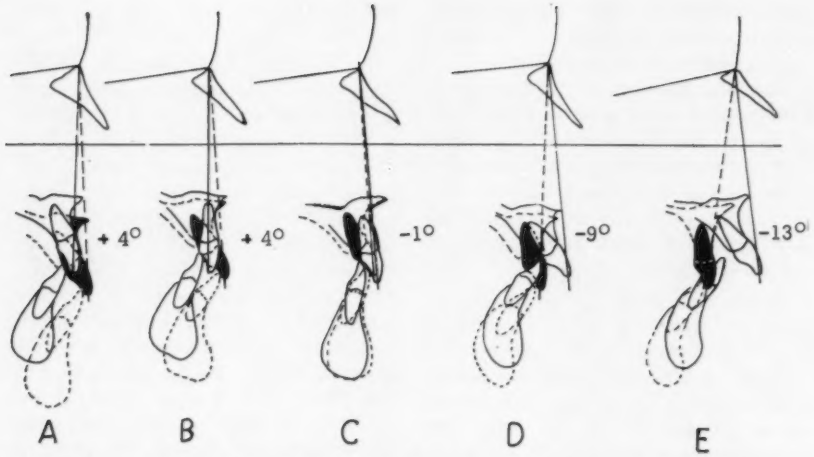

Fig. 13. Demonstration of the differences in the behavior of the tip of the upper incisor as measured from the angle SN-upper incisor. A) A four degree forward movement of the upper incisor in a nontreated Class I patient. This is normal male growth. B) Shows the torque and forward movement of four degrees of an upper incisor in a Class II, Division 2 which enjoyed excellent forward growth of the chin. C) This is an upward and posterior movement of an upper incisor in a Class II, Division 2 of a girl experiencing very little growth. High pull headgear was used in treatment. D) Illustrated is lingual movement of nine degrees of an upper incisor in a malocclusion treated without extraction and with cervical anchorage. There is tipping and slight bodily movement of the tooth. E) Shows the behavior of a severe Class II, Division 1 in a developing retrognathic pattern. The upper incisor was torqued lingually and moved thirteen degrees from N registered on the sella-nasion line.

influenced during treatment. Therefore, the angle SN-upper incisor (U-1) was employed using the finding of the controls as the general tendency in different malocclusions and facial patterns.

Upper Incisors

The SN U-1 in the Class I control was 82.7° and the Class II control was noted to be 81.2° at the start. Each group showed a tendency for the upper incisor to erupt farther forward (Fig. 13A). The Class I containing several protrusive cases averaged +1.2° and the Class II cases showed an average of +0.7°. In the treated extra-oral anchorage sample this angle was decreased 3.4° on the average (Fig. 13), often with no anterior bands placed; the average was 84.2° in the beginning. In the intermaxillary elastic sample the effect was less than half as much, showing only 1.8° decrease. In the combination anchorage cases the average was 85.4° at the start and was reduced to 81.2°, a change of 4.0°. A 5.4 mean decrease was noted in Class II, Division 1 cases treated with multiple anchorage (Fig. 13).

The upper incisor showed similar characteristics when measured in mm directly to the APo plane. The greatest change was observed in the headgear plus intermaxillary elastic cases which witnessed 4.5 mm retraction. In Class II, Div. 1 cases in this sample the average improvement of almost 6 mm was noted. These cases revealed that a mean of 9.0 mm protrusion was reduced to 3.1 mm. This mean was influenced by some Div. 2 cases in which

upper incisors were actually brought forward and torqued labially.

Lower Incisors

The lower incisor was studied serially by means of a perpendicular to the mandibular plane registered at the symphysis. The "horseshoe outline" of the cortical bone of the symphysis was employed for reference.

The average lower incisor was observed to move upward and backward with no treatment when related to the symphysis. In the Class I control cases starting from about 8 mm, the lower incisor moved backward 1 mm during the three years observed. The Class II sample starting at 9 mm retracted 0.4 mm in the two and one-half years. In the extraoral sample the lower incisor moved backward 1.4 mm on the average starting from 7.9 and going backward farther. However, a significant difference from either of the samples was seen in the intermaxillary anchorage cases. Here the average lower incisor came forward 2.0 mm with the pull of elastics on the lower arch (Fig. 6). *The average was noted in spite of the fact that almost one third of the cases received bicuspid extractions as a part of treatment.*

In the headgear and elastics anchorage cases, the lower incisor was found to also move posteriorly on the average. Starting with a distance of 8.2 mm from the reference line it changed to a more posterior position more than 1 mm. *Thus, in the correction of malocclusion about 3 mm forward movement of the lower incisor was saved with the headgear.* In the Class II, Div. 1 cases, some of which were treated by setting up mandibular anchorage with elastics from the upper denture or were treated with extraction, this average change was almost 2 mm in a backward direction after completion of treatment. A comparison of the latter two samples suggested a difference of about 4 mm in the position of the lower incisor by the end of treatment when differences in the end results were studied.

The relationship of the lower incisor to the APo plane in the one thousand case study was observed to be +0.5 mm with a standard deviation of 2.7. In the Class I sample the lower incisor was 1.3 mm forward and with growth went to 1.6. Actually, the APo plane moved backward over the incisor due to mandibular growth. In all the Class II samples the average incisor was located posterior to the APo plane at the start since point A was forward. In the control it was —.7 mm, the extraoral group —.3 mm, the simple anchorage group —1.2 and the compound group —.6 mm.

Except for the Class I control, after treatment records revealed a forward tendency of the lower incisor relative to A-pogonion in all cases. In the Class II control, a forward growth of the chin and pogonion explained the improvement. It improved to almost zero or directly on the APo plane. In the headgear treated Class II cases this change was greater. There point A reduction accounted for a greater change even with lingual movement of the incisor as described above. These cases finished 1.1 mm ahead of the APo plane on the average. The intermaxillary elastic cases were located +1.5 mm ahead of the plane at the end of treatment; the lower incisor was moved forward almost 3 mm without great reduction in point A in many cases.

In the multiple anchorage sample the lower incisor moved to +0.5 mm, exactly on the mean of the normal, and thus was changed —1.2 mm. However, this was accounted for in some cases by backward movement of the incisor in view of the movement of point A posteriorly and forward movement of the chin.

Lower Molars and Occlusal Plane

Changes in the lower molar teeth and tilt of the occlusal plane were measured. In the Class I and Class II control groups the lower molar showed almost identical behavior. It drifted forward 0.1 mm and erupted upward 1.5 mm average when measured from the symphysis on the mandibular plane. The occlusal plane angle to the mandibular plane showed a tendency to decrease with growth, i.e., lower in the posterior.

In the headgear sample the lower molar was prevented from erupting to that degree observed in the controls, i.e., only 0.8 mm eruption. Likewise the occlusal plane further decreased with treatment more than seen in the controls.

In the intraoral anchorage cases the lower molar moved forward 1.6 mm and upward 3.3; the occlusal plane tilted 3.4°.

The lower molar was moved forward only 1.1 mm in the multiple anchorage sample. That was only two-thirds the distance observed when elastics were emp'oyed alone; the occlusal plane still tilted 2.4°.

Upper Molars

The upper molar was measured from the posterior margin of the pterygomaxillary fissure perpendicular to Frankfort plane. Actually this point was the anterior border of the pterygoid plates at the pterygopalatine fossa. In the Class I controls 3.5 mm forward drift of the molar was noted; the molars of the Class II control cases drifted forward only 2.0 mm. With headgear the molar was moved backward 1.3 mm relative to the PTM line. When elastics were employed it still moved forward 1.3 mm. In the headgear and elastics cases extraction was employed in many instances; many arches were fully banded and the upper molar used for anchorage in retraction of incisors. However, it still drifted forward 1.2 mm in that sample.

Growth of the Nose

The nose grew 2.2, 2.6, 2.5, 2.5, and 3.5 mm in the groups respectively. A direct measurement was made from ANS to the contour of the end of the soft tissue of the nose. Thus, yearly increments of about 1.0 mm were observed on the nose although great variation was noted. Greatest changes were observed in boys at puberty and late nose growth spurts were suggested which corroborated Subtelny's findings[23].

Discussion

Michael Scriven[24] writing on *Logic of Explanation* and *Prediction in Evolutionary Theory Noital,* "There are specific occasions when we explain and predict by reference to the same laws. To predict we correlate present with future events—to explain we correlate present events with past ones. Roughly speaking the prediction requires only a correlation, the explanation more. Finding causes is harder than finding correlations".

For a long time orthodontists have sought an explanation of phenomena occurring during treatment. Until recently the 1938 appraisal of orthodontic results[3] has been the principal explanation accepted for behavior during treatment. Numerous other studies of growth[25] on the normal have likewise served to guide the clinical orthodontist. Many of the aspects of the 1938 paper are not substantiated in the present investigation; however, some aspects are still applicable. In order to clarify these points and add others of importance to clinical application with conventional treatment techniques the sequence of study included the cranial base, mandible, maxilla and teeth.

Changes in the Cranial Base

The average of no change in the cranial base was made from changes of up to almost five degrees in both directions with a standard deviation of 1.2°. The significance of cranial base relations has been discussed by Bjork[20] and by Ricketts[26] particularly as related to the nasopharynx area. It should be appreciated that the maxilla (point A) was found to grow forward at an almost identical rate as the anterior cranial base in the untreated samples (Fig. 2). For that reason the increase of length of the SN line was of interest. In a similar manner the glenoid fossa has been suspected of traveling backward together with the posterior cranial base; however, this is not a true relationship since the petrous and squamous portions of the temporal bone are largely related to the middle cranial fossa while basion is in the posterior fossa. Some individuals possessed a backward movement of the condyle and fossa without posterior growth of the basioccipital area (Fig. 4).

Laminagraphy is needed to study the variation of changes in temporal relationship. Practically, however, it appears that the jaw elements are driven apart by cranial relationships which become more obtuse while the jaw elements are brought closer together as the cranial base closes or becomes more acute. Individual cases were selected which bore out this contention (Figs. 2, 3). Thus, the *complete cranial base* change was of interest in the appraisal of behavior during treatment. Stability of the cranium was not true for all cases.

Changes of the Mandible

Brodie et al. studied mandibular changes by relating the mandibular plane to the Bolton plane and measured length increase of the mandible by measuring gnathion from registration point R and length by Go-Gn. In their sample the Class I and Class III patients were in general too old to show much growth. In the Class II cases the time interval was long, in some instances being five and six years between records and therefore difficult to differentiate growth from treatment. Even then some of the females grew only a slight amount. With second order bends and mandibular anchorage employed for treatment they showed that intermaxillary elastics caused a predominant downward and backward rotation of the mandible. Three treated cases by this procedure of elastics only and with different facial types are contrasted in Figures 6, 7 and 15.

It was felt that the facial angle and X Y axis angle were as critical and useful as any other method of studying the changes but were more revealing in determining type, therefore, possibly the best references for our purpose. The mandibular plane also was of growth significance. Therefore, combinations of the Frankfort plane and the Ba-N plane served as references to evaluate treatment. In the final analysis the change in the X Y axis angle and growth on the axis told the growth and behavior story.

A comparison of one hundred nontreated control cases over a three year period with treated cases revealed no difference in the quantity of mandibular growth as measured on the Y axis. However, better orthopedic developmental behavior of the mandible was observed with high pull headgear and vigorous elastics than with simple intermaxillary elastics due to less rotation (Figs. 8 and 12). Growth of the mandible was no better than normal tendencies seen in the untreated on the average. Individual cases attracted attention; however, cases to match their growth behavior could be duplicated in the nontreated youngsters.

Fig. 14. These tracings demonstrate the effect of treatment on the mandible as the upper molar is extruded or intruded with cervical or high pull headgears respectively. This patient had a Class II crossbite at eight years and ten months. Cervical headgear and expansion were employed; the molar was moved downward and posteriorly and the chin dropped straight downward as seen in the illustration on the left. At ten years the bite was beginning to open severely so a high pull headgear was used to intrude the molar from its original position. The chin then grew straight forward and the bite began to close again. Following this the patient was again given a cervical headcap and again the case experienced a bite opening from eleven to twelve years. At that time vertical elastics were needed to close the open bite and the case was finished with all permanent teeth present. The illustration on the right shows there was consistent upward and backward growth of the condyle and downward movement of the chin.

The amount of growth on the Y axis was similar in all groups studied, treated and untreated. An average of almost 3.0 mm per year characterized all groups and served as a guide for a starting hypothesis in a growth estimation technique. The standard deviation was 1.2 mm and the standard error ±.0075.

It was felt that no essential difference could be noted in the amount of growth in treatment or nontreatment groups and thus that orthodontic forces employed in this study had no stimulating effect on mandibular growth. Functional appliances or inclined planes were not included. It is hoped that patients treated with these kinds of appliances will be studied in the near future.

However, differences in the *direction* of growth of the chin were noted in the control and the treated samples. This became obvious when all groups were broken into prognathic and retrognathic patterns and then studied serially.

In the Class II control retrognathic cases tended to drop on the Y axis (Fig. 9) while the patients with chins located upward and forward tended to stay in that direction or proceed forward (Fig. 7). A scatter diagram tended to bear this out although the overlap was great. In prognathic patterns the facial angle tended to increase at a greater rate than the retrognathic cases. The mandibular plane angle showed a tendency to decrease or improve with growth in the prognathic cases in spite of the Class II malocclusion (Fig. 2).

The most interesting observation noted was the effect of different kinds of treatment on rotation or opening of the mandible (Fig. 14). The headgear tended to open the X Y axis angle in both the retrognathic and prognathic cases. This therefore was the ideal method in prognathic closed bite cases (Fig. 10). However, elongation of the upper molars was unfavorable in retrognathic cases. The author applied high pull headgear to the upper molars in those cases following that observation.

The effect of intermaxillary elastics in some of the retrognathic cases was disastrous (Fig. 6). When it is realized that these cases already possess greater length to the face than desirable and are subjected to an opening of two to five degrees more in the X Y axis angle, intermaxillary forces should be undertaken with extreme caution. This phenomenon was avoided in many of the Class II cases treated by multiple anchorage. In that sample the Y axis was noted to improve in many of the retrognathic cases. The difference in these cases was better mandibular anchorage conservation and preparation in an effort to depress the lower molar teeth. This was often accomplished with buccal root torque on the lower molars, Class III intermaxillary elastics, high pull headgear directed at either the incisors or upper molars or segmented arch therapy* in the upper buccal segments, but chiefly for the elimination of full correction by intermaxillary elastics. Thus, the selection of appliance therapy for these cases was effective in controlling the behavior of the chin. In some long faces, deep overbites were treated by intrusion of teeth rather than by opening of the mandible and further elongation of the face (Fig. 8).

Of deep concern are the factors which permit or produce the phenomenon of opening or closing the Y axis and rotation of the mandible with bite opening. It was noted that strong forward divergent or closed bite faces tended to resist bite opening except by intrusion of teeth. Retrognathic cases tended to open considerably, particularly as the lower molars erupted, the incisors elongated and the occlusal plane was severely tilted. In some cases the downward pull with cervical headgear tended to erupt the upper molar. Then on reversing the forces and depressing the molar, the chin would come forward. It would then be moved downward again as elongation again was experienced (Fig. 14).

It could be speculated that two factors may be at work, both related to neurophysiology. First, proprioceptive factors of the teeth probably play a role; the patient might avoid closing against traumatized teeth. Secondly, the muscle pattern and character of the muscles of mastication might play the predominant role. Strong closed bites might not yield to traumatic forces on the teeth and thus remain closed as the teeth are depressed into the alveoli (Fig. 7). A follow up of cases with intense neurophysical studies is indicated.

The final consideration is whether or not the form of the mandible is altered in these cases with different treatment. The condyle axis and mandibular plane need more thorough investigation. Perhaps our methods of superimposing need changing as would be suggested by the implant studies of Bjork[27]. Preliminary observation on the basis of independent behavior of the condyle and the border of the mandible suggests that the form of the mandible has changed in a slightly different

*Segmented arch therapy is taken to mean here the retraction of teeth without continuous arches and the correction of Class II in the buccal segments without attachments on the upper incisors.

manner in the cases treated by different procedures although the amount of growth was similar. However, any firm statement on this cannot be documented at this time due to lack of detail in this study regarding these factors.

Changes in the Maxilla and Teeth

Probably the most important contribution of the present work is that related to the maxilla and the upper teeth. The maxilla was studied relative to the profile and to the anterior cranial base. The change in facial contour would be explained only after the mandibular change has been assessed.

Our first question was whether or not point A represented the maxilla. When there was doubt, we took ANS and made two outlines for point A, one on the alveolus and the other on the projection of the root of ANS. The behavior of point A is to some degree related to change of the upper incisor with eruption and with torque forces applied during treatment (Fig. 15). For the most part it is fairly representative of conditions of change in the middle face.

The untreated samples tended to improve slightly in facial contour but this was due to mandibular growth because the maxilla showed a slight tendency to grow forward in conjunction with the eruption of the upper incisor (Fig. 5). For the most part the angle SNA did not change and the malocclusion got worse instead of improving. Individual cases however behaved differently.

Convexity was improved about one millimeter in the cases treated with mandibular anchorage alone. In extraction cases with severe torque during treatment much improvement was noted in individual cases (Fig. 15). However, in the headgear cases the difference was about three millimeters and the improvement in convexity averaged almost four millimeters in patients treated with a combination of anchorages.

These differences for the most part were discovered to be due to changes in point A. Registration on SN at N indicated that point A was retracted —2.7° with headgear alone. Considering a mean of +0.3° increase as natural behavior, the effect of the headgear alone was to reduce point A an average of 3.0°. With intermaxillary elastics alone this figure was —1.0°. With multiple anchorage a mean 3.4° retraction was observed. Generally speaking the headgear was effective at three times the rate of intermaxillary elastics on the behavior of point A.

The question naturally arises, is this an alteration of the whole maxilla? For this reason the anterior nasal spine and the palatal plane were studied. It was discovered that ANS went posteriorly together with point A although at a slightly slower rate. However, the palatal plane was tipped quite severely in many cases, averaging +1.6 against +0.2 in the controls.

The finding that the anterior nasal spine and palatal plane both were altered led to the speculation that the whole middle face was altered with treatment. This phenomenon was so consistent in fact that it could be anticipated (Fig. 10). Since alteration of point A was observed without forces applied to the anterior teeth and the fact that Class I cases went into anterior crossbite without forces directly applied to the anterior teeth both add weight to the possibility of entire maxillary alteration.

The study of maxillary alteration would not be complete without the study of the upper incisor. Therefore, the upper incisor was related to SN at N similarly to point A. On the average there was a slight forward movement in the Class II control but in the Class

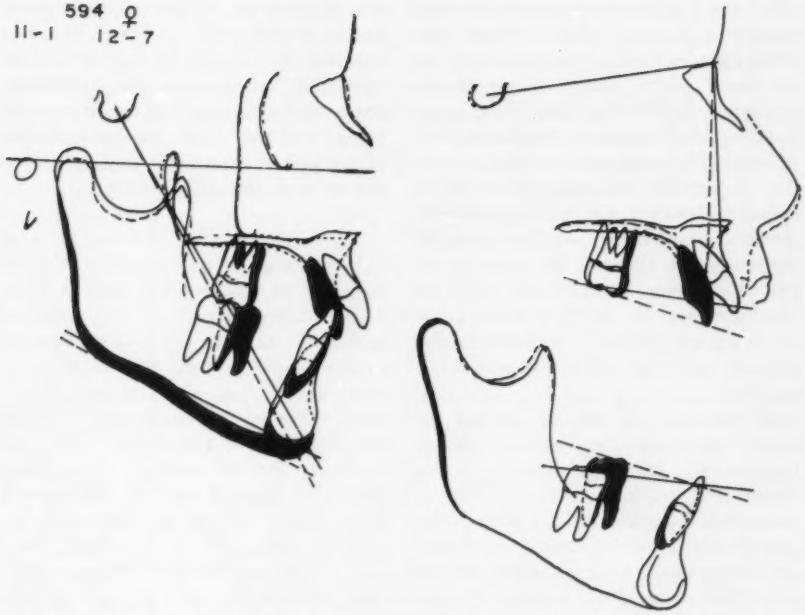

Fig. 15. Changes in a case treated by a modified-Begg technique. This severe Class II, Division 1 of a mesognathic type was grossly corrected in seven months although a longer period was needed to upright teeth and torque the upper incisors. The overall changes are exactly as would be expected with intermaxillary elastics being used at the start of treatment. The chin dropped downward and the mandibular plane angle increased slightly. The lower molar moved upward and forward excessively although held upright; the lower incisor was slightly intruded and moved lingually. There was improvement in the SNA angle but this was due mostly to the torque of the upper incisor and not to a complete alteration of the palate as seen in headgear cases. This should be expected in rapid treatment as was experienced in this patient. The upper incisor was torqued almost completely through the lingual plate of bone which I hope will respond with functional adaptation. An .019x.019 archwire, alternated with a .018x022 wire, with .019 Siamese brackets was used for torquing.

I it was greater (Fig. 13). It was necessary to move the incisors forward in some Class II, Div. 2 cases. In the headgear-only cases the incisors moved lingually even with no direct force applied to them. Mandibular anchorage revealed only a slight improvement and with multiple anchorage the effects were greatest. A most striking change of five or six degrees was noted in the retrognathic cases treated with multiple anchorage and extraction, but these cases needed it most. Fig. 13 shows an incisor reduced thirteen degrees which was about fifteen to sixteen mm.

In general it can be stated that for every three mm bodily posterior movement of the upper incisor there was a two mm reduction of point A and one mm of reduction of ANS. A similar improvement of the upper incisor was noted when it was related to the APo plane.

The lower incisor behavior in the untreated samples when related to the symphysis revealed a slight tendency for retraction with growth. This was

augmented in the cases treated by extraoral anchorage alone. Thus, the headgear contributed to retraction of the lower incisor with no mandibular appliance, possibly by function against the upper incisors. Malocclusions treated with compound anchorage also demonstrated a reduction of the lower incisor. However, in the mandibular intraoral anchorage cases the lower incisors moved forward an average of 2.0 mm. Thus, a mean difference of almost 4 mm in the behavior of the lower incisor was noted in the groups treated with different treatment techniques.

It has been of interest to me for many years to relate the lower incisor reciprocally to the denture bases. Therefore, the lower incisor relationship in millimeters to the APo plane (reciprocal denture plane) was found useful to evaluate the changes relating to dental base relationship. The incisor came forward in all samples, but the change in the plane itself accounted for the change as point A moved backward. It should be noted that the incisor after treatment was in an ideal reciprocal position for denture relationship.

A few outstanding observations are listed with regard to the molar teeth. 1) Without treatment in the two and one-half years of observation the lower molar tended to move forward only slightly, but erupted a 1.5 mm average as the occlusal plane was stable. 2) The lower molar remained stable for patients treated with headgear to the upper molars. There was no mesial drift of the lower on the average. It erupted slightly less than the controls 0.8 to 1.5 mm respectively. 3) The lower molar came forward an average of almost 2 mm with intermaxillary elastics and was elevated an average of 3.3 mm. Some cases showed 7 or 8 mm elevation. 4) The upper molar moved forward in the control group but backward with headgear. This was consistently evident in the deciduous cases. 5) The occlusal plane was held downward with cervical headgear and tilted upward from the mandibular plane with elastics. This finding is consistent with the 1938 paper.

Summary

Five groups of patients were selected for serial or longitudinal study. A Class I nontreated group of fifty patients and a like number Class II nontreated group served as controls. These averaged about eight years of age at the start of records although some patients were at the deciduous level and some were in the adolescent ages. Three groups of Class II patients of fifty each were selected for comparison with the control and with each other. Each group was treated by different appliance techniques; the first group was treated solely by headgear, the second by intermaxillary elastics and the third by a variety of headgear and mandibular anchorage techniques and full multiple banded appliances.

The method of study was cephalometric x-ray tracings. Areas studied were relative to the cranial base, the mandible, the maxillary components, the changes in incisor and molar teeth and the growth of the nose.

Several outstanding findings were observed. The cranial base angle revealed no average change but was made up of extremes in both directions cancelling each other. Growth on the sella-nasion line was 0.86 mm per year (S.D. ±0.3) or almost 1.0 mm per year.

The mandible did not seem to be affected in amount of growth by treatment. Growth on the Y axis was 3.0 mm per year (S.D. ±1.2). However the effects of bite opening and rotation of the mandible downward and back-

ward or upward and forward could be controlled to some degree by the direction of orthodontic forces. Different facial patterns behaved differently with treatment. These factors were discussed.

The maxilla was found to be altered by treatment when compared with the controls although a slight age difference existed in the samples. The palatal plane, anterior nasal spine and point A all tended to be altered by vigorous extraoral orthopedic forces, even when employed only twelve to fourteen hours daily. Vigorous continuous intraoral traction and torque modified point A without as much palatal and nasal spine alteration as seen with headgear treatment.

The malocclusions tended to get progressively worse with no treatment as the patients were followed in the control groups. Patients treated with intermaxillary elastics showed a forward movement of the lower arch as the occlusal plane elevated posteriorly and the upper incisors moved downward and backward. Prognathic cases showed stability in the lower arch, due to teeth deep in basal bone in short faces. Cases studied that were treated with segmented arch therapy or high pull headgear revealed that the upper incisor was moved in a straight backward direction or upward and backward.

Distal movement of the upper molars was accomplished with extraoral anchorage directed at the molars. The greatest change in upper incisors was noted with full appliances together with vigorous extraoral anchorage, good mandibular preparation and segmented arch therapy in the upper arch. Teeth could be moved bodily over distances more than a full centimeter from where they would have been had treatment not been employed.

The lower incisors tended to move posteriorly from the symphysis in the controls and the treated cases with the exception of those treated by mandibular anchorage alone. The evaluation of the lower incisor made from the APo plane was consistent with an uprighting of the incisor. In the mandibular anchorage cases the uprighting of the APo plane was less noticeable. Thus, in cases with convexity the lower incisor remained forward in a reciprocal relationship to the two denture bases. This confirmed the use of the A pogonion plane as a reciprocal reference to the lower incisor.

The growth of the nose was studied from the anterior nasal spine. The average was almost one millimeter per year in the samples studied. The older age groups demonstrated slightly more growth than the younger. The forward growth of the nose together with retraction of the teeth and mandibular growth accounted for the great esthetic changes frequently observed in the treated cases. When no growth occurred, the changes were due to tooth movement alone. Improvement in esthetics was not evident in the untreated cases over the age spans studied except for nose growth.

Conclusion

In order to evaluate the effects of treatment the final result must be visualized from the situation that would have prevailed with growth had treatment not been employed. It is not enough to simply compare the patient with himself at the beginning of treatment. Neither is it adequate to compare him with a normal growth standard. He must be considered on the basis of his individual likelihood. I sought to determine how the untreated Class II behaves at an age and time interval commonly treated. Thus different facial patterns were typed and studied.

The whole cranial base is important

as a reference. It sometimes explains unfavorable behavior and often accounts for success or failure in a very hidden and subtle manner. Direct reference from mid-sagittal landmarks to the glenoid fossa are needed, however, good x-rays free of paraphernalia of the head holding apparatus will help reveal location of the glenoid fossa.

Mandibular behavior is most conveniently viewed from the change in the Y axis. Length increase by growth and directional change by opening or closing constitutes this consideration. The findings suggested that the directional or developmental behavior of the chin *could be influenced by treatment techniques*. To some degree these were controlled by the orthodontist but the underlying basic pattern still predominated. It still appeared that the *amount* of mandibular growth was not influenced by treatment, at least by the appliances employed for this study.

We can no longer accept the maxilla as an immutable structure. Vigorous retraction force on the teeth, particularly parallel to the axes of roots, appears to prevent forward growth and even cause the maxilla to grow downward and backward. These forces must be transmitted to the suture lines which are the growth sites in the maxilla and theoretically respond to functional phenomena. The pterygoid plates and deep structures need further investigation but isolated cases even suggest alteration there.

The teeth change dramatically under the influence of good cooperation with extraoral devices even if worn only twelve hours per day. The force of intermaxillary elastics without steps to prevent upward and forward movement of the lower molars results in a backward rotation of the mandible, forward movement of the lower arch and results in a strain on facial musculature particularly in retrognathic cases. In other patterns it is often the method of choice.

Teeth can be intruded, extruded, tipped or moved bodily by choice of mechanical procedures. Treatment with full bands and headgear permits a wide assortment of orthodontic possibilities. The distal movement of the upper first molar was most evident especially during the transition from the deciduous to the mixed dentition or before the second molar erupted. For this reason early treatment seems advisable for maximum orthodontic orthopedic correction even at the deciduous dentition level.

Perhaps the profession has gone off the deep end in its concept of stability of the pattern, particularly as related to the maxilla. Individuals, with certain mandibular characteristics that predominate, do follow a general course as expected under a concept of stable growth. However, the eruption of teeth, as influenced by treatment, does have an effect on mandibular directional behavior and development. Perhaps these findings reopen the book for the possibilities of functional disorders in the etiology of malocclusion. Maybe we should look more at function of the tongue, swallowing etc., before the teeth erupt.

No one can study this work without obtaining an appreciation for growth. The proper use of growth information is that growth and natural changes *can* be employed to advantage in treatment. Needless extraction or needless tooth movement can be avoided. The same result might be obtained more easily for all concerned if growth and physiology are correlated with treatment, rather than treating the patient on the basis of static relationships.

These findings suggest that the orthodontist at least should recognize the difference between (1) the possibilities of the orthopedic guiding and directing

the growth of the jaws and, (2) the possibilities of treatment of other cases which must be considered on a static or nongrowing basis either due to finished growth or because treatment is too rapid to reap the benefits of growth.

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Editor's note. Raw data upon which this paper is based may be obtained from the author.

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DISCUSSION

Dr. R. C. Thurow

Dr. Ricketts has undertaken a tremendous project and his presentation today is actually only a preliminary report on a part of the data. Please keep this in mind as I discuss some of the questions raised by this report.

The first consideration in this type of investigation is the sample which provides the source for the data. In the tabulations we have only means to work with, with no indication of ranges of measurements, but these means do show some important differences between groups.

The control, or untreated Class II group, was observed from 8.1 to 10.6 years of age. Those treated with a cervical appliance were about six months older (age 8.8 to 11.1). The group treated with combined anchorage, both cervical and intraoral, was started at about the same age that the cervical group was discontinued (11.0 years) and treated until age 13.8 years. The first two groups could be considered to lie in the pre-puberal age range, while the combined anchorage group was treated at an age where puberal growth changes might be expected to be near their peak.

It was not stated explicitly whether treatment was complete at the time of the final observations. If treatment was not complete, some comparisons could be misleading. On the other hand, if treatment was considered complete, there could be some reservations about the cervical cases.

Growth and eruption are not normally complete at 11.1 years of age but there are strong indications that cervical therapy is most effective when continued through this period.

One of the most recent studies on this subject is an unpublished investigation by Doctor D. H. Ketterhagen which included sixty-one cases treated with extraoral anchorage and more than one hundred controls. Cephalometric records for each patient included intervals both with and without extraoral therapy. Measurements of cuspids and bicuspids showed consistent downward and forward movement during the periods without treatment. This was true before treatment, after treatment, and in the untreated controls. During intervals where extraoral therapy was applied, all of these teeth showed a marked change of direction toward the distal, even before eruption.

There is a tacit recognition of the importance of growth in Ricketts' choice of treatment for his patients in different age groups. In the younger children with a greater expectation of growth, he has used cervical therapy alone. It is in the older group which is approaching puberty that he has used extraoral and intraoral therapy in combination. Of course, this is oversimplifying the picture by generalizing from mean ages. Within the groups we could find many exceptions and many other reasons for his choice of treatment which might run counter to this general trend.

As for the measurements themselves, my overall impression is that they show considerable change due to treatment but very little difference between types of treatment. Here again, we have only mean values to work with but most of these showed differences which were only fractions of a degree. Doctor McGonagle has just pointed out the problems which we encounter at this level of accuracy.

Disregarding the problem of accuracy entirely, there is still the question of the almost certain wide overlapping of the different groups. When the means are so close together, a scatter diagram of the measurements would probably be almost the same for every group. In a situation such as this, it seems more important to me to study the differences between the individuals within the groups than to try to locate the mean of one group in relation to another almost like it.

Another factor in the comparison of the two forms of treatment is the elapsed time. The average time of treatment for the cervical cases was 2.3 years. Those treated under combined anchorage thereapy were measured over a period of 2.8 years, six months longer. When the treatment changes are corrected for this difference to show *change per year*, many

of the initial differences all but disappear as you can see here.

	Cervical Anchorage		Combined Anchorage	
	Total Change	Annual Change	Total Change	Annual Change
Contour angle	-3.1	-1.30	-3.8	-1.35
S-N-A	-2.7	-1.18	-3-1	-1.11
S-N-1	-3.4	-1.48	-4.1	-1.46
1-AP (mm.)	-3.2	-1.4	-4.5	-1.6

The figures before and after treatment raise still another question concerning the selection of the original groups. Were the more severe cases selected for treatment, with the less severe placed in the control group? The mean figures would seem to point toward this conclusion. The following tables show the mean values for three measurements which are closely related to esthetics:

	Before Treatment	After Treatment
Angle S-N-A		
Control (Class II)	79.6	80.1
Cervical anchorage	82.5	79.8
Combined anchorage	82.7	79.6
Angle S-N-1		
Control (Class II)	81.2	81.9
Cervical anchorage	84.2	81.1
Combined anchorage	85.4	81.2
1 to AP (mm.)		
Control (ClassII)	5.1	5.7
Cervical anchorage	6.9	3.6
Combined anchorage	7.5	2.9

Apparently, the groups selected for treatment showed a more severe original deformity. Treatment changed the angles S-N-A and S-N-1 to a value almost identical to the initial measurement for the untreated controls. The upper incisor was about two mm more protrusive in the original treatment group than in the controls. Treatment reduced the protrusion of the upper incisor to about two mm less than the controls, as measured by its relationship to APo.

These differences seem to indicate the operation of some form of selection, but we can only guess at the source. Perhaps Dr. Ricketts unconsciously leaned toward correcting the more severe malocclusions, but it is more likely that the parents of those patients with the more severe deformity were more strongly inclined to proceed with treatment. In any event, the difference is there, and it should be reckoned with in any comparison involving the control group.

Means can vary considerably, even with groups as large as the fifty which were used here. I would like to close with a suggestion for a simple test which will help to keep this problem in mind as we study data such as this. Divide each sample in half, without any selection, and calculate the means and other values separately for each half. Comparing the results for the two halves with each other, and with the complete sample, will do much to maintain our awareness of the vagaries of numbers.

An Evaluation Of The Accuracy Of Cephalometric Tracings

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INTRODUCTION

Roentgenographic cephalometry has emerged from the research laboratory to become a diagnostic necessity in the clinician's operatory. On the surface it would seem that this should be a source of great pride for the researcher as he sees his laboratory infant mature into useful adulthood. The truth is that the researcher is sometimes dismayed by the unbridled enthusiasm of the clinician. For one thing, the disciplined scientist is aware of certain artifacts of his instruments and of the superimposed human error.

This investigation sought to determine the latter source of error in the manipulation of roentgenographic cephalometric data: the relative accuracy of tracings, made independently by five selected men, of the same head x-rays. It was felt that this question was as basic to the interests of the clinician as to the laboratory worker.

METHOD AND MATERIALS

Films of three subjects were used: (1) lateral and frontal films of a well preserved skull with a full complement of teeth in acceptable occlusion, using a Wehmer head positioner and a Picker x-ray tube; (2) the lateral film of an eighteen year old white female; and (3) a series of films of a white girl who was x-rayed in a Broadbent-Bolton cephalometer at eight. eleven and fourteen years of age. In each instance five sets of duplicate films were made from the original plates by the solarization technique[1] and each participant was given a number known only to the writer.

In the first exercise the men were instructed to trace certain basic landmarks: nasion, Bolton point, sella, orbitale, mandibular and maxillary outlines and incisors, cuspids, first molars, third molars, both right and left, above and below. Where bilateral structures were involved, averages were taken. They were instructed to establish a Bolton triangle and registration point. The author did not trace the plates for fear of influencing his handling of the material. His part was purely reportorial.

The various tracings were superimposed and two of the most dissimilar were chosen to illustrate the discrepancy shown in Figure 1. However, one may note, the points seem to be uniformly off which led me to superimpose on certain anterior landmarks that are readily determined: nasion, incisors, and mandibular symphysis (Fig. 2). It was immediately obvious the discrepancy in Figure 1 was due to an error in choosing a base point, i.e., Bolton. Other than this mistake the tracings in Figure 1 are remarkably similar. This strikingly illustrates the need for extreme care in choosing base points, particularly in doing serial work to study either growth or treatment changes.

In the frontal head plate the participants were instructed to outline the cranium, mandibular borders, nasal aperture, orbits, cross section of zygomatic arch and incisors and first molars, both right and left, above and below.

Read before the Edward H. Angle Society, Colorado Springs, October 1959.

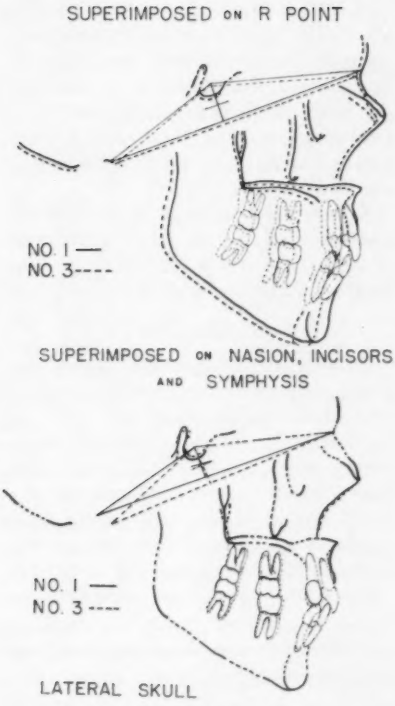
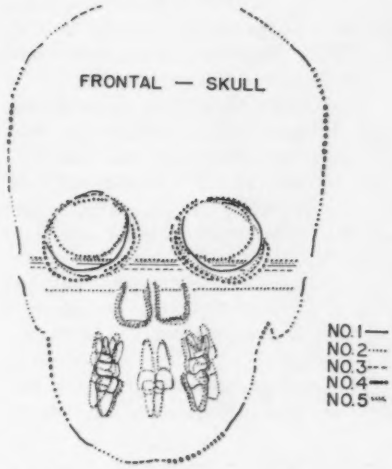


Fig. 1. Above.
Fig. 2. Below.

They were also asked to draw a vertical line bisecting the right and left nasal aperture and a horizontal line connecting the most superior points in the bilateral cross sections of the zygomatic arches. The intersection of these two lines was called point M and was used for superimposing the frontal tracings. There was considerable discrepancy in this exercise when a composite was made of all five tracings, as shown in Figure 3. Again I resorted to superimposing on more readily defined structures such as cranial and mandibular outlines, as illustrated in Figure 4. Again it was obvious that the selections of the base points were at fault; the horizontal line (most superior points on the cross sections of the zygomatic arches) had led in large part to the error observed. There was also considerable variation in the tracing of the orbits in each illustration, but this is understandable due to the outline



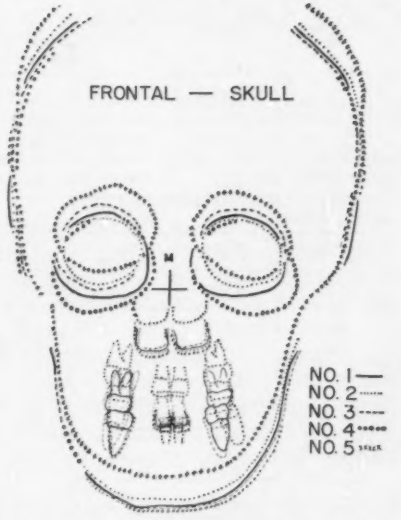


Fig. 3. Below, superimposed on M point.
Fig. 4. Above, superimposed on cranial and mandibular outlines.

with which we are dealing. Also, it was suspected that most men do not routinely trace their frontal films which may also contribute to the error noted.

The next procedure involved tracing the lateral head plate of an eighteen year old female, and the participants were instructed to do a Downs' analysis. Porion was established by the author on all the duplicates in the hope this would reduce the degree of error.

There was a high degree of similarity and in most measurements the discrepancy was three and one half degrees or less (Fig. 5). In one instance a six degree difference was noted in the upper to lower central incisor measurement. This may have been due to a slight variation in establishing the long axes of these teeth; due to the diverging lines, a small error would be quickly magnified.

The next procedure was to use the serial set of complementary head plates of a girl at eight, eleven and fourteen years. The same basic points were traced as in the lateral skull films, but the cuspids and 3rd molars were eliminated. Again the Bolton triangle and registration point were used and a composite was made of all five tracings at the various ages.

It was most striking to see the degree of similarity in these tracings at all three age levels; the eleventh year stage is shown in Figure 6.

Discussion

This small sample and simple investigation can not be statistically evaluated. Consequently it has its limitations in analyzing the relative accuracy of cephalometric tracings. The large number of variables opens the study to justifiable criticisms. Inasmuch as a duplication technique was introduced, the quality of the films (but not their accuracy) could be ques-

TABULATION OF DOWN'S ANALYSIS RESULTS

J. L. 18 YRS.	NO 1	NO. 2	NO. 3	NO. 4	NO. 5	RANGE
	SKELETAL					
FAC. A.	83	81.5	82.5	81.5	84	2.5°
A. OF CON.	+5	+6	+5	+5	+4	2°
A-B PL.	-4	-5.5	-5	-5	-4	1.5°
F.H.- M.P.	25	26.5	24.5	26	23	3.5°
Y. AXIS	66	66.5	65	67	64	3°
	DENTURE					
OCCL PL.	10	13	11	12	11	3°
$\overline{T}$ TO $\underline{1}$	136	135	136	131.5	130	6°
$\overline{T}$ TO OC. PL.	22	21.5	22	25	22.5	3.5°
$\overline{T}$ TO M. PL.	+8	+7.5	+9.5	+10	+11	3.5°
$\underline{1}$ TO APo. PL.	7 M	8 M	6 M	6.5 M	6.5 M	2 M

Fig. 5.

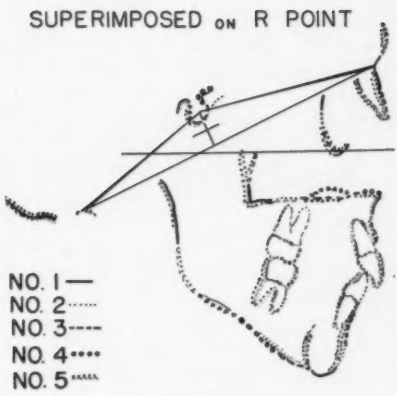


Fig. 6.

tioned. It would have been better to have all the participants trace the original head plates; in the interest of time we resorted to duplicates. It is also true that many men utilize both models and dental x-rays when tracing head plates and these aids were not furnished. It might have been a profitable expansion of the study to have included more angular and linear measurements.

The selection of men who do more tracing than the average orthodontist may have influenced the results obtained. Perhaps their work should be compared with a group that does only an occasional tracing.

It was interesting to note the degree of accuracy when the series was traced. This may illustrate the advantage one has when he can examine both "before" and "after" films where one particular head plate of a series requires checking a questionable point. The importance of carefully choosing base points was illustrated but it is probable that if the same individual is making the same relative error, this constancy will somewhat soften the effect of his misjudgment. However, the error will quickly manifest itself when the work of several independent investigators is compared.

Conclusion

Men will continue to measure and compare head plate tracings and rightly so. Although this study pointed out many encouraging aspects of tracing accuracy, it also illustrated that we must be cautious in accepting any and all findings based on cephalometic tracing. We must draw on our basic knowledge in growth and development, our knowledge of treatment result and effects, as well as fundamental facts that are known in related basic fields of research.

I think this study could be enlarged and refined and that this would continue to aid our understanding of the accuracy ascribed to cephalometric tracings.

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Discussion

Dr. Allan G. Brodie

I find myself in a somewhat embarrassing situation as I start the discussion of these papers since all of the essayists and the two discussers who are to follow me are former students of mine. I have tried to escape from this dilemma by inducing the other two discussers to assume the responsibility of handling the real criticism of the work and to reserve for myself a few generalities on the subject of research. If any of my random remarks happen to apply to these papers, I make no apologies to these men. They have probably heard critical remarks from me before.

The first question I should like to

pose is, "Just what is research?" There are a number of misconceptions about it and probably the commonest is that it requires some peculiar attributes of the mind, some measure of queerness in order to be a research man, or to do research.

A truer concept of research is embodied in the statement that it consists of one part of inspiration and ninety-nine parts of perspiration and anyone who has done any amount of researching will vouch for the truth of this. When one of yesterday's essayists casually mentioned that there were 53,000 measurements involved in what he was talking about, I could almost smell the perspiration.

The next question is, "What should be researched?" This can be answered very quickly. Anything that interests us is a good field. In this connection I am reminded of a talk I heard given by President Bowman of Johns Hopkins one night a number of years ago. He said that he was frequently asked this question by graduate students. President Bowman said he had this same answer for all of them:

"Pick up any textbook in your field and read until you come to the words, 'It may therefore safely be assumed —' stick your spade right in there." Certainly we have paid the price of too many assumptions. The researcher tests these assumptions; he is looking for facts.

How should a research problem be approached? First, it is necessary to ask a question about something in which you are interested. It may be something that you may have assumed has been known for a long time, yet an objective search for definite proof reveals that it is lacking. This makes an excellent place to start.

Next, think about how you are going to ask your question; and note that it is *a* question, not questions. A lot of thought at this point is frequently rewarding because one is apt to find himself working backward beyond his question to other questions that are fundamental to it. Finally, a critical question presents itself and now it may be found that the whole complexion of the original question has been changed.

There has been too much research undertaken, particularly of a clinical nature, that sought to answer too many questions at once. This invariably leads to confusion because we are dealing with a multitude of variables. Take one question at a time and get it out of the way before starting the next.

The next step is to select a method that will yield the answer. There are numerous examples in our literature of work based on a method that could not possibly yield the type of answer that was sought. If a method is quantitative in nature, don't try to make it yield qualitative answers.

After the method has been selected it must be tested for accuracy and we have seen a beautiful example of such testing this morning by Dr. McGonagle. Similar testing has been done since the introduction of cephalometric roentgenology and has always led to the same conclusion; viz., that the human equation is the largest source of error in this technique. Every man who contemplates studies of this sort should test in a similar manner to determine what his own weaknesses are.

Now the experiment or study must be planned in such a way that the findings can be trusted. One of our first concerns will be our sample, its derivation, its size and its control. These factors do not enter into all studies on living forms but loom largely in many of them. The objective in all cases is to control every possible variable except the one with which we are concerned.

If we are going to subject our ex-

ample to an experimental procedure, such as orthodontic treatment, we must know how the sample would have behaved had it received no treatment. In Dr. King's work and that of Dr. Ricketts we have seen the use of controlled samples.

You might say that you did not see evidence of King's control. The reason for this was that the control had been worked out by others and the findings had been considered reliable. Ricketts, however, had a population that was homogeneous and wanted both his experimental and control groups from that population. This is even better.

Now I come to a discussion of the presentation of the material and here I may do a bit of jabbing.

A presentation should always be pitched at the level of the audience. If one is speaking to one's peers in the field, and here I mean men who have done similar work in the field, one can use technical terms and expect to be thoroughly understood. If however, the audience is composed of listeners who have less than an expert acquaintance with the material, one should lower his sights. And of course, if one is speaking before the P.T.A., the sights should be lowered still more. Always shoot at the feet because, even then, you are apt to be over their heads.

In the preparation of reports, unless one is unusually gifted, it is necessary to revise, revise and revise again. Difficult writing makes easy reading or easy listening. To sit down, dash off a paper and expect someone else to understand it is too much of a strain on an audience. Papers should be written once and rewritten four, five or six times, each time with the jaundiced eye of the critic. And make it short; remember, there are no souls saved after the first thirty-five minutes.

Finally, the careful and respectful use of language is essential if we expect to be understood by others. The use of colloquialisms such as, "toe hold" and "buttons on the chin," are not even accurately descriptive of the things they are supposed to represent, much less understandable. Many times such terms are confusing even to people who might be expected to be familiar with them.

Use terms that are commonly accepted by people not only in our own science but in related sciences. Not to do so lowers us in their eyes.

Dr. Raymond C. Thurow

I will have to admit that Dr. Brader and I were more than a little concerned at the prospect of following Dr. Brodie as discussers. Fortunately, all three of us decided to divide our assignments in advance to avoid duplication, but even this seems rather presumptuous at this point. Certainly there was no danger that I might be able to duplicate what Dr. Brodie has just said.

Dr. McGonagle should be complimented on the very effective way in which he has demonstrated the problem of cephalometric accuracy. In fact, his demonstration was so vivid that I feel it calls for a word of caution.

Variations such as we have just seen can be easily seized upon as evidence of unreliability, to the point of actually negating valid cephalometric findings. To those who might attack cephalometrics on these grounds, I would like to ask the man whose every application of orthodontic diagnosis and therapy is blessed by one hundred per cent success to cast the first stone.

For as long as men have attempted to correct malocclusions, they have recognized and grappled with their limitations. This recognition of limitations has been an important stimulus in the constant improvement of orthodontic technics and their application.

The problem in cephalometrics is much the same. We do not have micrometer accuracy and it has never been seriously claimed. Perfect accuracy is unattainable in any field. In cephalometrics the accuracy which can be attained routinely today is more than enough to provide a valuable source of information about the human head.

Reliability *is* dependent on accuracy, but it is much more dependent on interpretation. Assuming a higher level of accuracy than can be attained will certainly lead to unreliable results. This is a problem in every field of measurement and at every level of accuracy. Reliability is achieved by recognizing the level of accuracy which can be attained and then acting on the basis of that information. If we do this in cephalometrics, it will continue to serve us as one of our most useful tools of investigation. We are indebted to Dr. McGonagle for reminding us of this problem in such a clear and graphic fashion.

Variations In Profile Change And Their Significance In Timing Treatment

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INTRODUCTION

The age and sex of a patient beginning orthodontic treatment with a Class II, Division 1 malocclusion may determine his potential for certain quantitative changes in the hard and soft tissue profiles of the face. This report concerns some of these growth and treatment changes in boys and girls at various ages. The data were secured from cephalometric headplates taken before and after orthodontic treatment and the information obtained therefrom supports our concept of treatment timing.

Most of us agree that both age and sex may determine the potential for improvement during treatment. That potential, of course, is growth along with a plasticity of the alveolar process that apparently is not as great when growth slows or ceases. How growth occurs and where it occurs are well documented; but we have only an educated guess as to how much will occur and specifically when. We know that the timing of growth differs according to sex. We can visualize how growth helps in our concept of treatment for Class II, Division 1 malocclusions; but knowledge of the amount and timing of this growth is nebulous. In analyzing quantitative changes as they relate to the sex and age of the patient, it may be possible to anticipate what changes to expect in treating Class II, Division 1 malocclusions at a given age in boys and girls. A knowledge of possible quantitative growth and treatment changes for various ages may provide a rational basis for timing the start of orthodontic treatment.

Read before the Edward H. Angle Society, Colorado Springs, October 1959.

REVIEW OF THE LITERATURE

The pubertal growth spurt has been referred to as an aid to treatment. Recently Graber (1955) noted that the chances of success were greater if treatment were coordinated with the pubertal growth spurt; but, also, he acknowledged the unpredictability of growth. He indicated that the best results were most likely in girls when treatment is started between ten and twelve years of age and in boys between twelve and seventeen years of age. In keeping with such a concept many orthodontists plan treatment whenever possible to coincide with an active growth period. Yet, on further inquiry as to when this growth is to occur in good quantity we receive many diverse opinions.

A different approach was expressed by Kloehn (1947) in which he urged early treatment of Class II, Division 1 malocclusions to inhibit forward growth of the maxillary teeth and alveolar process while normal growth carried the mandible forward. He held that early treatment was important because of a "declining rate gradient of growth of the jaws and alveolar process."

Turning to the profile, Lande (1955) made some observations regarding males that are pertinent here. His was a cephalometric study in which he superimposed headplate tracings on the sella-nasion plane at nasion. The trac-

ings were oriented on the Frankfort plane. He observed that the mandible became more prognathic relative to the brain case and the maxilla. Thus, the convexity of the face tended to decrease as age advanced. Similarly, Bjork (1947) observed that the mandible tended to become more prognathic with growth in males. His study was done with groups of males twelve years of age and from twenty-one to twenty-three years of age. On the basis of these findings it seems that the orthodontist may accent and facilitate some of those changes that are natural and to be expected regarding a reduction in the convexity of the face.

Epstein (1949) presented cephalometric evidence of the effectiveness of extraoral anchorage in holding back the forward growth of the maxillary first permanent molars. This would seem a necessary requirement for restricting profile points on the maxilla such as the incisors and point A. In a cephalometric study, King (1957) corroborated Epstein's findings and added that extraoral anchorage apparently slowed the forward growth of subspinale (point A). Furthermore, he noted that a relationship existed between starting age and the quantity of change that occurred.

Material and Method

The data in this study came from before and after treatment headplate tracings of one hundred and three consecutively treated Class II, Division 1 malocclusions. In terms of treatment, all of the cases had a common denominator; the Class II condition was corrected by extraoral anchorage, either a neckstrap of the kind described by Kloehn or a few cases of headcap or both. All cases had full or partial appliances in addition to attachments on the maxillary molars.

The time interval between headplates

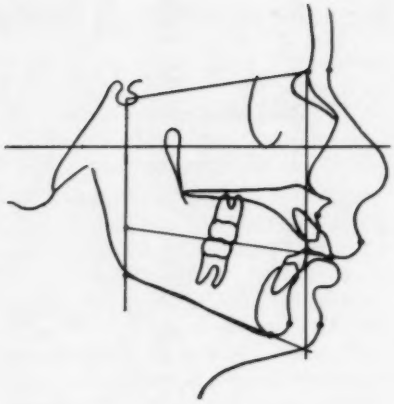

Fig. 1.

was usually from twenty-two to twenty-six months. The data derived from these were classified according to the sex and the age of the patient at the start of orthodontic treatment. The points measured appear in Figure 1 and are indicated by the heavy dots. They are, reading from top to bottom: nasion, subspinale (point A), the maxillary central incisor, and pogonion. The soft tissue points were measured opposite nasion, the upper lip, and opposite pogonion. The vertical height was the distance from nasion to menton. These measurements were recorded in millimeters. The degree of occlusal and mandibular plane changes was recorded to check its effect on the position of pogonion.

All headplate tracings were oriented on the Frankfort horizontal plane. To minimize error in each pair of tracings the Frankfort plane was located in the pretreatment tracing and was then transferred to the posttreatment tracing by superimposing the two tracings on the sella-nasion plane registered at sella.

In evaluating profile changes I have selected nasion as the reference point, although with growth, of course, it

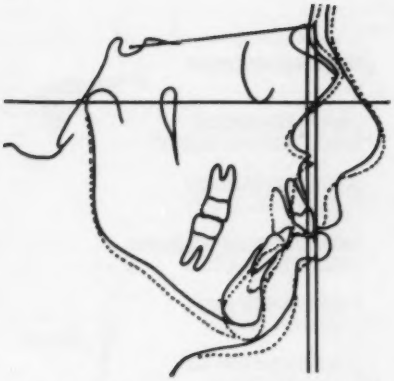

Fig. 2. Nasion planes in superimposed before and after treatment tracings.

moves forward relative to sella or registration point or basion. In assessing the changes that occurred, a line was drawn from nasion, perpendicular to the Frankfort plane and extending the full length of the face as in Figure 2. For convenience I called this line the nasion plane, and it served as a plane of reference in both tracings.

The anteroposterior changes that occurred at the several points mentioned above were measured relative to this plane. For example, in the pair of tracings superimposed in Figure 2, it was determined that nasion grew forward three millimeters by measuring the distance between the nasion planes in the pre and posttreatment tracings while they were superimposed at sella. Next, point A was measured relative to the nasion plane in the pretreatment tracing, as in Figure 3A. It was four millimeters in front of the nasion plane. In the posttreatment tracing, Figure 3B, point A is on the nasion plane. The net change is then posteriorly four millimeters which was recorded as minus four. Changes at the other points were recorded similarly with anterior movement indicated by a plus reading and posterior by a minus. In this instance point A was held back three millimeters and moved back one millimeter.

The vertical measurement was recorded simply as the distance between nasion and menton as in Figure 3. This was of interest along with the mandibular and occlusal plane changes because vertical increase, change at pogonion and tipping of the mandibular and occlusal planes could all be interrelated.

Convexity of the face according to Downs' (1949) analysis was measured to provide an index of the severity of the malocclusion. It was felt that this would avoid errors in the conclusions due to differences in the severity of the malocclusions between the various age groups. These differences were not too significant and will not be discussed.

I shall omit tabulations of the data for the absolute values are not as important as the general comparisons between the age groups and between the sexes. For the sake of brevity the data

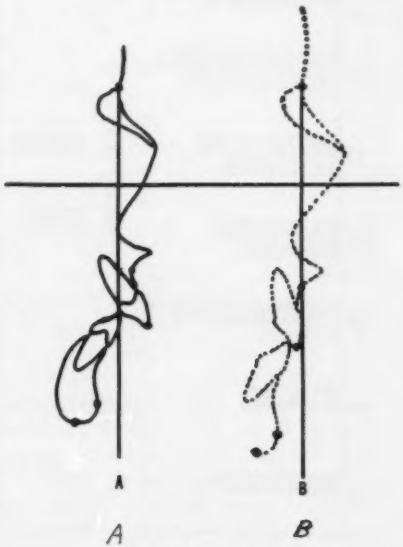

Fig. 3.

appear in graphic form to show the differences in behavior that occurred due to sex and the age differentials.

Findings

Distribution of the sample is shown in Table I.

TABLE I

Age	8	9	10	11	12	13	14	15
Males	3	6	7	9	12	5	5	3
Females		10	14	10	6	5	4	4

The forward growth at nasion is shown in Figure 4 and the changes that occurred at point A in Figure 5.

Fig. 4. Forward growth of nasion.

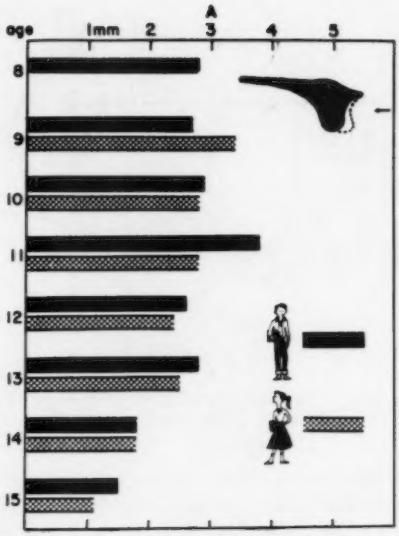

Fig. 5. The net posterior changes recorded at point A.

Discussion

Before commenting on the findings I want to point out some limitations imposed by the method. In recent years it has been popular for orthodontists to present evaluations of treated cases. In this discussion it is convenient to present data as a statistical analysis and herein may lie trouble, as was pointed out by Thurow (1958). In this study we are dealing with averages and usually the average will not apply to any one individual. When evaluating treated cases it has often been customary in the past to group together children of several different ages for statistical analysis and draw conclusions from such a classification of the data. With no standard regarding age, individuals who may be growing actively and individuals who may not be growing at all have been grouped together for statistical purposes. The author did this in a paper published in 1957. The above grouping of the

data on children using as a standard the chronological age along with the type of malocclusion and sex of the patient has its limitations; but some errors regarding growth may be minimized by this handling of the data.

Other variables are apparent that could affect the validity of the results. Some seemed practically impossible to eliminate in a clinical study using linear measurements. Variations in size between individuals make one millimeter of change in a small girl far more significant than one millimeter in a large boy. The cooperation of the patient in wearing the extraoral appliance or in following other instructions can affect the duration of treatment. Variations in pain tolerance affect the amount of pressure permissible in the appliances. Differences between individuals in the rate of growth would directly affect the quantitative changes. All of these factors and many more, such as the health and well-being of the child, size of the roots of the teeth and even the amount of chewing function could introduce errors in the findings. Above all, remember that in applying any conclusions from this study one is playing the averages.

It is apparent that younger individuals have a greater potential for achieving favorable changes than older ones; and, of course, boys have a greater growth potential and thus greater potential for improvement than do girls. The data lend further weight to facts which we already know. Also, they do provide some information about timing treatment relative to the quantity of change needed for a satisfactory improvement in boys and in girls. With older patients they may better equip us to prognosticate those changes that we can reasonably expect to occur during treatment.

It is not now possible to establish exact values of expected improvement for any age group. However, the data, as shown in graphic form, indicated generally a greater amount of growth and favorable change occurred per unit of time in the younger age groups. The growth process and possibility for orthodontic improvement extends over many years and orthodontic treatment uses a small segment of the total. In planning treatment relative to the amount of change needed, a problem with a severe denture base discrepancy obviously would require more growth to be treated satisfactorily than one less severe. In the severe cases it seems that treatment should be timed to start earlier.

The changes that occurred at point A and pogonion confirmed the recommendations of Kloehn regarding the desirability of starting treatment early. The slowing of growth with advancing age decreased the possibility for reducing the prominence of point A as well as obtaining favorable growth response indicated by pogonion. Furthermore, the decreasing quantity of change that occurred as age advanced emphasizes the fallacy of depending upon the so-called pubertal growth spurt to provide sufficient growth for a desirable improvement in the more severe problems.

The findings seem to support, in part, the observations of Graber regarding girls, that treatment should start between ten and twelve years, but they indicate inclusion of nine year olds and possibly even younger groups. The data do not support Graber's statement that twelve to seventeen years is the best time to start boys. It appears, depending upon the severity of the problem, that it would be desirable to start them as early as eight or nine years and possibly no later than thirteen years of age if good growth at nasion is to accompany a favorable change at point A and a minimum of

unfavorable change at pogonion.

The work of Lande referred to earlier indicated that nasion, point A, and pogonion may grow forward simultaneously and in approximately equal amounts. Forward growth of nasion and pogonion while holding back or moving back point A by proper manipulation of the maxillary denture is perhaps the ideal situation for optimum improvement in treating a Class II malocclusion.

Diagrammatically, nasion, point A, and pogonion represent a triangle standing on end as in Figure 6. Nasion and pogonion indicate the base of it with the apex at point A as in Figure 6A. If nasion and pogonion move forward equally and point A remains stationary, the triangle has flattened much as we would desire in treating a Class II malocclusion, Figure 6A. If nasion and pogonion grow forward and point A moves back, the triangle becomes a straight line making possible an even better result, Figure 6B. If pogonion fails to move forward, the triangle does not change as much, Figure 6C; but if point A moves back as well as pogonion and no growth occurs at nasion, we have a much less favorable change as in Figure 6D. This is an oversimplification of some possibilities for changes at nasion, pogonion, and point A; but changes at these points do noticeably affect the results of treatment.

Obviously we should plan treatment to make the most of the favorable changes that growth offers and also to make the most of these changes per unit of time expended in treatment. To do this we must anticipate favorable forward growth in the upper face indicated by nasion and in the lower face indicated by pogonion. If change at these points can be favorable and, if in the middle face we can restrict or move lingually the maxillary incisors with the alveolar process indicated by point A and, if the upper lip follows along, then we have a favorable improvement. A failure of one or more of these factors obviously limits the improvement.

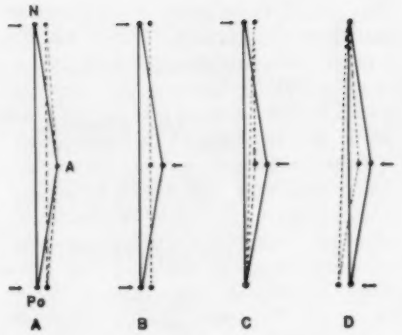

Fig. 6.

According to this sample of cases the growth expectancy at nasion for boys is reasonably good at all ages from eight through fifteen; but more growth apparently occurred per unit of time in the younger age groups. We may say that about one millimeter of forward growth occurred per year at eight, nine and ten and somewhat less from eleven to fifteen, thirteen excepted. In girls the amount constantly diminished from one millimeter per year at nine years until at age fourteen none occurred.

Pogonion is the problem. In boys, according to Lande and Bjork, this point should grow forward at least as fast as nasion and perhaps slightly more so. Under the influence of orthodontic treatment it did not, Fig. 7. The events surrounding this unfavorable behavior are a separate discussion in themselves, but some of the factors that seem to influence pogonion during treatment are: vertical growth, depth of the overbite, use of intermaxillary elastics, facial type and severity of the malocclusion. The significant fact here is

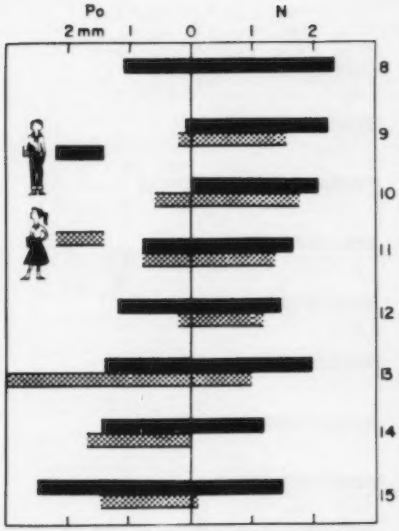

Fig. 7. Bars on the right of the zero or base line, which represents the nasion plane, indicate the forward growth of nasion as in Fig. 4. The bars on the left indicate the amount by which the forward movements of pogonion *lagged* behind growth registered at nasion.

that the changes were more unfavorable as age advanced.

Fortunately, one modifying circumstance prevailed; to some extent the unfavorable change at pogonion seemed to be a reversible change. In many patients the mandible tended to come forward somewhat with growth and the settling of the teeth following orthodontic treatment. A headplate taken a year or two following treatment usually is encouraging regarding pogonion.

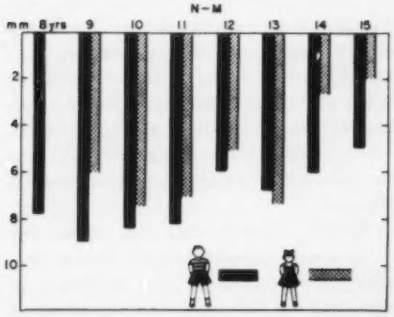

Fig. 8. The vertical change between nasion and menton.

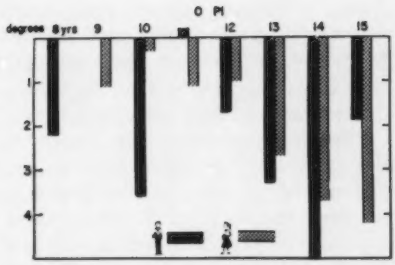

Fig. 9. Occlusal plane changes.

During treatment vertical change tended to decrease with advancing age, Fig. 8. Concurrently pogonion dropped back with advancing age. It is possible that vertical growth tended to cancel out the bite opening that apparently occurred in eliminating the deep overbites that are a part of Class II malocclusions. It may be that the alveolar growth that occurs with increase in height of the face facilitated correction of the deep overbites. When alveolar growth slowed, the bite was opened at the expense of tipping downward the occlusal and mandibular planes, Figures 9 and 10. As the mandible tips downward, it tends also to drop backward. We have, then, two factors which if present may favorably influence the profile change at pogonion

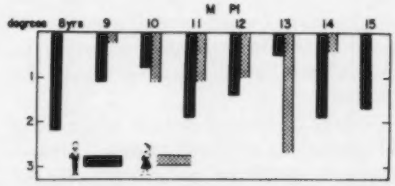

Fig. 10. Mandibular plane changes.

during treatment: namely, the forward growth of the mandible and vertical growth of the alveolar processes.

It is our impression that the orthodontist can influence most, in addition to the teeth, the anterior region of the maxillary alveolar process, approximated by point A. Furthermore, the area around point A seemed most amenable to change when growth was active. This point, Figure 5, exhibited a definite pattern of decreasing change relative to advancing age. In both sexes the change that occurred was approximately three millimeters in the eight, nine, ten and eleven year old groups. At twelve years the amount decreased slightly. At fourteen and fifteen it dropped off to between one and two millimeters. The younger age groups had the advantage.

What makes these changes more significant is that at the same time point A is moving or being moved posteriorly, nasion and pogonion were also changing. For example, in the nine year old group, pogonion did not drop back much, Fig. 7. It was growing forward at almost the same rate as nasion, while point A moved back approximately three millimeters. This was a worthwhile improvement. In the thirteen year old group, point A changed almost as much as at nine, but nasion grew forward much less, particularly in the girls. Even more striking is what happened at pogonion. It dropped back one and one-half millimeters in boys and more in girls. To achieve the same amount of profile change as indicated by the three points on the triangle shown earlier, point A would need to be moved back much more. Again the younger patients had the advantage.

Before finishing we want to comment briefly on the soft tissue profile, Figures 11 and 12. Those points opposite nasion and pogonion followed closely the

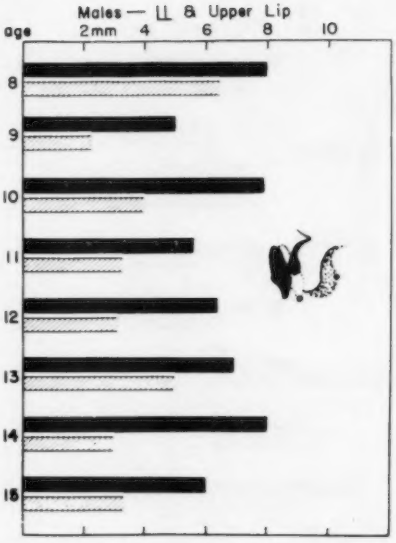

Fig. 11. The bar graphs illustrate the changes in the position of the upper lip relative to the maxillary central incisor. The solid black bar represents the incisor and the diagonally-lined bar, the upper lip.

skeletal changes and little change occurred in the thickness of the soft tissue. Thus these changes were not shown graphically with the others. Changes in the upper lip were of interest because they bore a definite relationship to change in position of the incisors. Generally, for each millimeter of posterior movement of the incisors, the prominence of the upper lip decreased about one-half millimeter. Exceptions to this were thin-lipped children in whom the labial change followed more closely that of the incisors. Conversely, much less change occurred in prominence of the upper lip in thick-lipped children.

Specific procedures for planning treatment, bringing into focus the changes relative to age and sex as described in this discussion, are beyond the scope of this paper. The consideration of age and severity of the prob-

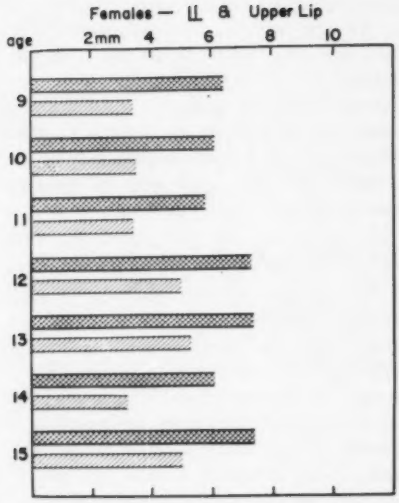

Fig. 12. The same changes indicated in Fig. 11, but for females. Bars with crossed lines represent the upper incisor and the diagonally-lined bars, the upper lip.

lem as primary factors in timing and planning treatment offers many possibilities regarding the prognosis and treatment for Class II, Division 1 malocclusions.

With the above facts in mind relative to nasion, point A, and pogonion in particular, I think it is possible to be selective in planning and timing orthodontic treatment of Class II, Division 1 malocclusions. For cases of moderate severity or moderate denture base discrepancy or less, it may be expedient to let dental age determine the time to start treatment. In many of these moderate cases it is usually more convenient and efficient in appliance manipulation to have most of the adult teeth in place when treatment begins. In more severe cases with a severe denture base discrepancy, it seems better to consider the severity of the problem, the quantity of change necessary for improvement, the sex of the patient and the chronological age in planning treatment, rather than dental age and convenience in appliance manipulation.

Summary

To summarize, the author analyzed certain quantitative changes in the profile of the face that occurred in treated Class II, Division 1 cases. The data were classified according to sex and the age at the start of orthodontic treatment. Generally, the growth and treatment changes that occurred were more favorable in the younger age groups. In discussing timing, orthodontic treatment seemed indicated early in proportion to the severity of the problem in both sexes with less leeway apparent in timing the start of treatment in girls than in boys.

Medical Arts Square

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Discussion

Dr. R. C. Thurow

Dr. King's paper will be discussed in detail by Dr. Brader but I would like to touch on one phase of his cephalometric evaluation. This is the frequently used procedure of fixing the angular relationship between the SN line and the Frankfort plane for serial evaluations. The usual method of accomplishing this standardization is to measure the angle between SN and Frankfort on one film (usually the first) and then adjust the position of porion on the other films to maintain the same angular relationship.

The reason for using this procedure is twofold. First, Frankfort provides an essentially horizontal reference plane which maintains a natural orientation for study. Second, porion is too variable to provide a reliable reference for measurement of serial changes.

The disadvantage in using this procedure is that we are actually measuring our serial changes to SN, not Frankfort. What we speak of as the angle to Frankfort is actually the angle to SN plus or minus the angular correction which has been applied. This means that it is impossible to evaluate any changes which might be influenced by a change in the relationship between the Frankfort plane and the SN line.

It seems to me that it would be very useful to make a new effort at locating a posterior point on the Frankfort plane, or a plane closely approximating Frankfort. Ricketts uses the external auditory meatus which would be much more desirable than a part of the head positioning apparatus. Brodie has mentioned work done at Illinois using a point on the internal surface of the cranium in the same general area. If adequate reliability could be established for either of the points, or for some other point, it should be a definite improvement over our present methods.

As one of the few cephalometric planes with a direct relationship to the integumental face, Frankfort deserves serious attention and study. Its importance is obvious from the very fact that it is found to be useful in a large number of studies even with its present limitations.

Dr. Allen C. Brader

We are listed on this program as discussers. Now, to me the word "discussion" does not necessarily imply the application of favorable comment. Personally, I do not subscribe to the principle of burning souls for their own salvation. In any event, by agreeable division of the material, I have the pleasure of discussing Doctor King's work primarily. Like all good studies and like the work of all good students the report which he rendered poses many additional questions.

I do not purport to know the answers to these questions; however, I feel that scientifically there is enough reasonable doubt as to the positiveness of some of these statements to cast them into the air for your consideration.

Doctor King spoke in his introduction about the plasticity of the alveolar process being less when growth slows or ceases. Perhaps this is a semantic problem, but I think that the choice of the word "plasticity" leaves that open to some question. Whether the statement is true or not may be a matter of interpretation. For example, we are all aware of the differences in treatment that we experience when treating children as opposed to treating adults, yet we all treat adults; and, in most instances, it has been my clinical experience and I think yours, that the adult patient is frequently rendered a successful service.

Also, there is a tremendous difference while we are thinking about plasticity,

whether we are thinking of moving individual teeth or groups of teeth. I am not sure what I gathered from the use of the word "plasticity." I think that King was implying greater osseous change than we have been accustomed to thinking about heretofore. Certainly Doctor Ricketts bore on that subject too, when he spoke about the extensive changes which he felt he observed, particularly within the maxilla, under the application of strong extraoral forces. These are things which I think we were not considering following the Brodie, Downs, Goldstein and Myer report of some years ago.

Now, as far as growth is concerned: this implies quantity, time and place. You divide quantity by time and you get rate, and the dynamics of growth implies direction. I would like to pose this question: Can we assume that growth is always in a favorable direction for the individual? There is little evidence, I think, in the reports given that we are capable of changing quantitative growth, that we are capable of changing the time at which it occurs, or therefore the rate. There is definite indication, however, that we may be able to alter the direction of growth.

There is at least one view of growth which is held by some of our colleagues in orthopedics who hold that growth is an almost immutable expansive force. Orthodontists are in the habit of speaking rather glibly about restraining growth and this is an alien concept to at least one of our allied fields.

Again, what is the evidence available to show that the degree of improvement with treatment is greater in quantity if the cases are treated during active growth spurts? I suggest that it is possible that treatment duration may be reduced by treating during these accelerated growing periods, giving us a mental picture of greater change only because the same quantity occurs within a lesser time.

Now, about the timing of treatment, I would like to cast this question into the air: Do untreated Class II, Division I cases routinely get worse in increasing annual increments following the establishment of occlusal interdigitation? Do Class II cases become "more Class II" after molar relations are established? There have been numerous reports, Lande, Bjork, Ricketts and others, that the angle SNA remains constant. This would not imply a worsening of the situation. Furthermore, Ricketts reported that the angle SNPo improved one degree in his *untreated* sample.

How much is one degree? I think this is a related question. We measure these angles in degrees, but they are not the same thing when applied to various areas of the face. For example, an angle measured from nasion to point A would have a leg of about fifty-five or sixty millimeters in length. By actual measurement the chord of a one-degree angle at fifty-five or sixty degree length is one millimeter, and on this basis I think Doctor Ricketts felt that he could translate directly linear measurement in millimeters from point A to his facial plane to an equivalent figure in degrees; however, if that same angle of one degree is extended to the area of pogonion, which is, in the usual face, a distance of 115 to 125 millimeters, we then find that the chord of a one-degree angle is the equivalent of two millimeters. This means the same number of degrees needs interpretation, I think, when you are reporting these figures.

With regard to the matter of timing, if these untreated cases do not become worse with increasing age, then it would seem to me that timing of treatment is not necessarily geared to our knowledge of growing, but that it is possible that the peripheral consider-

ations may deserve added weight, for example: the availability of tooth material, the longterm effect of muscular imbalance, the degree of the severity of the problem, parental pressure and other factors. It appears to me that too early treatment of the so-called borderline case risks prejudgment of the child with respect to the eventual facial outline, the severity of the problem, and perhaps even the amount of arch length deficiency. It is conceivable that after additional growth the treatment plan may require a change.

With respect to the data which Doctor King reported, I would like to say that the observed changes in selected points along the profile, such as point A, I found a bit confusing. This appears to be a matter of change in which point A is posterior relative to the plane, but is anterior relative to its original position. Simultaneously the change in point A is an absolute one with respect to its original spatial orientation, and of course this leads to some confusion. The way it was explained to me, such change occurred something in this fashion: Consider a man called "A" on a station platform who boards a train which we might call the anterior facial plane, and as soon as he boards the train he proceeds toward the rear of the train to his compartment.

At the time he begins his steps toward his compartment the train pulls out of the station. Now, his position relative to the train is becoming more posterior. His position relative to the station is vastly anterior to what it had been. The important thing is not what direction the train travels or how far or fast it goes toward its destination, but whether the man is on the train when it gets there. So then, there appears to be a decided relationship between point A and the facial plane which we are setting as an objective in treatment.

About Doctor King's grouping in the slides which he showed, I would like to inquire if the age classes listed were determined by the age of the original headplate. This is the way that it seemed to read to me and, if that would be true, the changes recorded over the twenty-two to twenty-six months reported would not be attributable to the group age posted on the graphs. It might be necessary to select the median age or change the age in some manner to improve relation to the interval which it represented.

Of course, the class sample size was small. I say this very kindly because anyone who has undertaken to do such work understands very clearly the problems involved in accumulating massive samples for evaluation.

Again with regard to the graphs which were shown I would like to inquire whether the recorded changes represented the total change occurring over the approximately two-year interval. It seems to me that they did. If that were true, I think that the findings might be more valid or more useful, perhaps, if they had been reduced to annual increments. I think that this would contribute to the objectives toward which these people are working. King and Ricketts have been working along a definite line — I think that they are trying to eventuate a degree of prediction, or a state of knowledge which would give them a reasonable anticipation for the behavior of future patients.

About the slides which Doctor King showed, the slide on point N indicated that the magnitude of the rate change is about a half a millimeter from the age of eight or nine to thirteen. I would suggest that the quantity is within the range of experimental and operator error. I don't feel that this is a quantity of change which is significant. As to his slide on point A, the maximum rate change between eight and

fifteen is the order of about one millimeter. Again, I question the significance of such a quantity, although there did appear to be a definite trend established.

As far as Doctor Ricketts' paper is concerned, I shall mention it only in so far as there was a relationship between both of the papers presented; it is very difficult to discuss raw reported data, of which there were volumes; however, I think Ricketts' paper is an attempt to quantitate the necessarily dynamic situation of growth *and* treatment and to compare the natural happenings with those which are affected by treatment procedures.

The utilization of knowledge of annual incremental change at selected points for which there is a reasonable degree of expectancy would appear to be a valid system to use in some effort to predict, estimate or assess the future possibilities of our problems; however it is considered, I think that all treatment planning, all analyses, encompass in some degree and in some manner an effort to evaluate the future of the patient. I can't conceive of a treatment plan which does not attempt to evaluate what will become the frame of reference within which we will eventuate our dental arrangement. It seems to me that Doctor Ricketts' work is a noble effort to quantitate what has been heretofore largely a subjective procedure with most us.

Doctor Krogman once said to me, "We must recognize the frailties of techniques," and surely any effort to predict the framework for the future of our patient has many frailties. I am sure that Doctor Ricketts and Doctor King would both readily admit to this. It was Krogman's further suggestion that we must temper our techniques with a kind of reasoning that permits us to be practical about things. He suggested that, "Idealism may be our wish, but adequacy is our goal," and I think there is much truth in this notion.

In closing, I think that there might be some comment made about the future of these studies. It would be interesting, for example, to observe what would be the longterm effects of these treatment procedures and, to note whether or not the treated case would tend to return in the direction of its original pattern. These are suggestions for additional studies which surely must follow the fine papers presented by King and Ricketts at this meeting.

The Field Concept In Orthodontics

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When one examines the programs of orthodontic societies now, and for many years past, he finds that articles dealing with the practical side of orthodontics predominate. Much has been written about case analysis and treatment planning, about appliance design and force application, about new materials and new technics. The emphasis has always been on the clinical aspects of our specialty. Relatively few papers touch on the basic philosophies underlying the practice of orthodontics. Attempts to articulate a broad view of tendencies within the profession have been overshadowed by views which are narrow and insular and concern themselves with restricted problems rather than with real philosophies of treatment.

The reasons for this situation are easily found. For one thing, a general approach to the subject would seem to have no bread and butter value in that no specific practical applications can be made of it. Moreover, general statements are frequently vague and indefinite, whereas what the man at the chair wants is information on how to do the job at hand. Then, again, it is easier to attack a problem than to think about it. The image of the philosopher, who detaches himself from a problem in order to see it more clearly, does not fit in with our concept of the man of action meeting his problems head on — and eventually solving them through the process of trial and error. This attitude, however, can easily be shown to be erroneous because, without realizing it, the way we think determines the direction our research will take and how it will affect, ultimately, our practical procedures and technics. For example, most people believe that missile research began with the V2 rocket developed by the Germans from 1930 to 1945. In point of fact, the pioneers in this work were two Russians, Meshcherski and Tsiolkovski whose work was published in the 1890's, anticipating future work by more than forty years and giving them a clear claim to a first in this field.

Taking a square look at our profession, we note that while technical procedures have multiplied as evidenced by the vast increase in gadgets, devices and attachments whose merits are persuasively presented in slick, profusely illustrated modernistic catalogues, which are now printed in separate sections, and while more and more emphasis seems to be given to generalizations of cephalometric data into diagnostic systems in which the individual seems to be lost, the basic problem still stares us in the face.

Cases seem to relapse — teeth tend not to stay where we put them. Adverse forces appear to plague our efforts and some unseen hand seems to reach out to undo our careful efforts. The fact remains that over a period of time, teeth tend to return to their original configurations. Why is this not more apparent? For one thing, we do not follow our cases long enough. We take models after treatment and, due to the static effect of plaster models, we tend to think of the result as remaining at this point. Many times, on viewing models taken two or three years after completion of treatment where

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the case seems stable, we are surprised to find that retainers are still being worn at night. Models taken many years later, however, clearly show the relapsing tendencies to a marked degree.

Moreover, we tend to minimize the situation by overlooking slight relapses. These cases, we say, are pretty good — and when we think of the severe relapses, of those which flagrantly have failed — we seem satisfied.

These relapses, or changes in configuration as I prefer to call them, could only have resulted from the action of adverse forces which continued to operate long after treatment. We have not, because we do not see them, realized either their potency or their constancy.

These adverse forces constitute our problem. And since forces in general belong to the domain of the physical sciences, let us turn to these disciplines for a better understanding of our problem.

The century in which we live and into whose sixth decade we now enter is particularly notable for the tremendous strides which have been made in the physical sciences. These developments have been made possible because, underlying the many discoveries and inventions, one could discern a hard core of basic theory which gave support and direction to the research. Many of the concepts dealing with such diverse and abstruse subjects as relativity, quantum mechanics and nuclear physics seemed strange and unreal when viewed in the light of everyday life. Surely there would seem to be no relation between them and the science and practice of orthodontics. But there is, however, one concept which, with slight modification, can be applied to the domain of orthodontics with interesting results. I refer to the concept of a physical field.

In physics, the word field is given to some "condition" prevailing throughout a continuum. By a continuum I mean a domain, a place where something can act. This continuum is thus a spatial thing and may refer to a gravitational field around a planet or to an electromagnetic field around the armature of a motor. For example, the temperature in this room may be said to constitute a field so that a thermometer placed in various parts of the room could measure it. These measurements would show it to be a variable field. Contrarily, measurements made on the gravitational field of the earth would show it to be a permanent field.

In this paper, we extend the notion of a field to the orthodontic situation. We attempt to answer the question: Is there a field surrounding the dentofacial complex and acting on the elements of that complex in a manner analogous to the action of a physical field? And how would the postulating of such a field influence our thinking about orthodontic problems?

It will be noted at the outset that the word "field" can be used in two different ways with regard to its meaning. In the first meaning, when we speak of the field of orthodontics, we refer to the science and practice of orthodontics as applied to the prevention and correction of malocclusion of the teeth. The field of orthodontics in this sense is what we do as orthodontists.

In the second meaning, we refer to the space or region which surrounds the dentofacial complex much like a magnetic field surrounds a magnet — a space in which forces are continually operating. At no time is the human denture free from these forces. On the contrary, it is immersed in them throughout the life cycle.

The two meanings are perfectly clear and distinct. However, in order

to avoid possible confusion, I have called the second field, the "orthofield". The orthofield, then, is defined as a physicobiological continuum surrounding the dentofacial complex. It can be thought of as consisting of the sum total of the forces which play upon the denture at any given time in the life cycle of the individual.

The physical aspect of the orthofield arises from the fact that the action of the muscle systems is expressed as a physical force. To these muscle forces we must add the other forces such as those due to the action of the functioning of the TM joint and the contact forces of the occlusal inclined planes of the teeth.

The biological aspect of the orthofield arises from the potentials stored in the mechanism and released on the denture as the pattern of growth and development unfolds. These are highly complex in nature and can only be understood when viewed as a whole. Successful treatment must be geared to the unfolding of this pattern.

By referring to the orthofield as a continuum, I mean that not only does it act in space, but also in time. A proper knowledge of this time gradient will help us to know when to institute treatment to achieve best results. Contrarily, any attempt to oppose its action will invite failure — for then we would be competing with the orthofield.

As the organism develops, the hereditary component which is present at birth is already molding the developing denture. Forces are released according to stored potentials and the whole acts in time to produce a progressive effect. Growth and differentiation are under the influence of the genes, and the whole interplay of forces gives rise to the morphogenetic pattern which, as it develops, tends to assume a stable configuration. When disturbed by the introduction of external forces such as appliances, the morphogenetic pattern tends to return to its original configuration when the forces are withdrawn. We designate this morphogenetic pattern to be one of the components of the orthofield.

As the morphogenetic pattern develops, it can store up potentials which do not immediately manifest themselves because they are prevented from acting. Aberrations of growth or intrusions such as adverse habits can retard the normal development of this pattern. Frequently, proper treatment will redirect the development into normal channels. One example of this is seen in cases of mandibular displacement where proper force application is followed by substantial improvement in a short time. Another example occurs in selected cases, where arches can be expanded to receive crowded teeth and stability of end result can be achieved without the sacrifice of dental units.

But the morphogenetic pattern is only one component of the orthofield concept. There are several other components. One of these components is the orthodontist himself. He affects the patient directly for he exerts force through the appliances which he manipulates. As such he must be considered a part of the orthofield. Through his education he learns to choose the time and degree of the force he releases on the teeth. His skill and adeptness influence in no small measure the attainment of treatment objectives. It is easy to see that were the patient to be placed in the care of a different orthodontist, the patient's orthofield would be changed. This emphasizes the fact that the field is that of the patient. The operator only contributes to it during the time when he applies force to the teeth.

While the patient is under his care,

at no time should the operator force his concepts of treatment on the patient in an arbitrary way. Rather, he should try to ascertain the particular field of the patient and modify his treatment in harmony with that field. This means, in a practical way, that arch forms should not be fixed, the same for all patients as they too frequently are. It does not mean that tip back bends should be made always at forty-five degree angles. Perhaps certain cases may do well with those slight bends, mild in degree, which have disparagingly been labelled "Illinois bends." The tip back bends employed should always be suitable to the needs and responses of the patient, factors which can be ascertained by the preliminary encounters of the operator with the patient's orthofield.

As the operator completes his treatment, the forces which he has imposed are withdrawn — but the orthofield continues to act until equilibrium is restored. Now what does this mean? This means that with the withdrawal of treatment forces the residual forces of the orthofield start to act, tending, according to physical law, to produce equilibrium. This equilibrium does not occur at once; it occurs only in conjunction with the potential of the morphogenetic pattern so that the effects may sometimes be prolonged for years. If the treatment factors synchronize with the individual field, a stable and acceptable result is secured. If they do not, as frequently happens, adverse changes occur.

Another component of the orthofield concept is represented by the patient himself. In the first place, his psychological makeup determines whether or not he will like his orthodontist, whether he has a desire for treatment. This desire makes for cooperation, a most important factor in treatment. Through good cooperation he will keep his appointments, avoid unnecessary breakages, wear his elastics or headcap as instructed and in this manner he will actively influence the end result of treatment. We are all too familiar with the patient whose cooperation during the first part of treatment is very poor with consequent lag in treatment response; suddenly there comes a point when the desire on his part to get through with treatment overcomes his inertia. He then religiously wears his elastics and in a short time the desired relations are established. Indeed we should never overlook the contribution of the patient to the orthofield.

Another factor which operates indirectly on the orthodontic environment is the influence exerted by our culture, the one in which we live. When, through economic conditions and desire for social status, people are motivated to come to our offices, they bring with them certain ideas of esthetics which influence us. These ideas, plus the concept of esthetics which we have as orthodontists, determine the dental arrangement which we impose on the patient and which we call normal occlusion. This arrangement seems to be the same for every patient, the same rotation-free and proximal contact arrangement, with no overjet and little overbite and with the long axes of the incisors at a certain accepted angle to each other. Little do we realize that this pattern is an arbitrary arrangement which we impose on the patient, a culturally approved relation, but not one which the patient's orthofield must necessarily accept. The modern concept of normal occlusion does not emphasize the individuality of the patient. He may exhibit a discrepancy in the sum of the diameters of the upper and lower incisors which would indicate a variation in the degree of acceptable overbite and over-

jet; or he may have a discrepancy in basal bone necessitating reduction of dental units. In either case the ideal occlusal arrangement would have to be modified. In practice, however, this is seldom done. What happens is that we place the teeth in normal occlusion and then hope that a condition of balance has been reached between the various forces. If such a balance is attained, then the esthetics we desire will have been achieved in an acceptable manner and stability will result.

Too often, however, with the cessation of treatment, after discontinuance of retention, the dental units tend to return to their original configurations. The culturally imposed arrangement may then be said to be incompatible with the force pattern of the orthofield.

No one can deny that retention changes are a major problem in orthodontics. Several months ago an essayist in a paper given before the Chicago Association of Orthodontists showed a case with a cuspid to cuspid fixed retainer which had been on over two years and lamented that he wished someone would tell him what to do with the case as he was afraid to take off the retainer. He sensed the forces waiting to move the lower incisors into an undesired relation.

And, Dr. Charles Tweed whose method of diagnosis and treatment is asserted to confer stability of end result has a note in the manual which is used in his course to the effect that cuspid to cuspid retainers should be left on for three years. His purpose would seem to be to allow the growth forces to subside and thus remove an adverse factor from the orthofield.

The postulation of an orthofield surrounding and acting on the denture helps us to understand more fully the limitations of our treatment efforts. We see an ever present condition with which we have to reckon. No longer will a nicely treated case be one which will satisfy G. V. Black's normal arrangement of the teeth with normal arch form, no rotations, proper proximal contacts, with acceptable overbites, with accepted cephalometric standards satisfied, and tissues healthy. In addition to the aforementioned esthetic criteria, a nicely treated case will have a position of equilibrium in relation to the orthofield. It will stay put. Furthermore, the thought of this field, lurking in space and time, ready to pounce on our efforts, will tend to tone down rash generalizations as to cure-all theories of case management. Neither uprighting over basal bone, poring over cephalometric tracings, using light wire technics, nor removing dental units will solve our problems. We will realize that other factors, many still hidden, remain in the field to plague us as we attempt to maintain carefully treated cases.

We will be stimulated to search for new factors and turn our efforts to basic research as we attempt to ascertain the characteristics of the orthofield.

The concept of the orthofield will give us a broader view, a wider sweep of canvas than we have had before. For example, when we read where Mershon says: "You can move teeth to where you think they belong — Nature will move them to where they will adapt themselves to the needs of the organism." We will understand by this that the "needs of the organism" will be the limitations (and possibilities) of the orthofield.

Also, we should recall the well known words of Dr. Angle on retention, where he says: "After malposed teeth have been moved into the desired positions, they must be mechanically supported until all of the tissues involved in their support and maintenance shall have become thoroughly modified, both in

structure and function to meet new requirements."

When we read these lines we should tend to question the idea that teeth can be maintained in any position no matter how well desired merely by being maintained in that new position long enough. We should somehow like to feel that the new position was in harmony with the orthofield — even if we didn't exactly know where this field was. We should expect some relapse. In the quotation it appears that Dr. Angle did not expect any.

We would agree with Oppenheim on the other hand when he said that teeth should be permitted as much freedom as possible during retention thus allowing for quicker readjustment of bone. For in this way the orthofield could have a chance to operate freely on the treated denture.

An appreciation of the orthofield will cause us to pay more attention to the individual and adopt methods of treatment which emphasize individual response. As an illustration of one of these methods we cite the method of Dr. Abraham Goldstein which has been described in the literature. This method is to remove the upper archwire periodically during Class II treatment and study the pattern of relapse. One develops facility in appraising the action of the orthofield as one sees the musculature react to proprioceptive reflexes set in action on the freed dentition. Interesting responses can often be noted and one gains valuable insight into the prognosis of the case through this simple device.

In conclusion, must we always be at the mercy of the orthofield? Is the orthodontic problem, then, insoluble? While this contingency has to be faced, one should never stop trying to increase understanding and knowledge since conceivably the complete field may some day be delineated in all of its complexities.

If, with the poet, we could grasp this sorry scheme of things entire, we would shatter it to bits and then remake it to our heart's desire. But this we cannot do; our only course is to plan, to work, and to hope.

55 E. Washington

Discussion

Dr. Allan G. Brodie

Dr. Schwartz' presentation affords an opportunity to discuss certain fundamental matters that are all but completely neglected today in orthodontic circles. While not peculiar to orthodontics, this neglect is more glaringly apparent here because of the extremely rapid development of orthodontics as the most popular dental specialty. One has to go back only as far as World War I to find orthodontia, as it was then called, the most unpopular and neglected dental field. Looked upon as a racket by even the dental schools it was shunned by all except those who gained intimate knowledge of it through personal contact with orthodontists. Such contacts were rare because by that time the specialty had drawn apart from the general field of dentistry.

In the face of a forty year decline in the dentist-to-population ratio there has been a constantly accelerating increase in the orthodontist-to-population ratio since the early 20's and, although the demand for dental and medical training has shown unmistakable signs of leveling off these past several years, the demand for orthodontics continues to increase. This is not altogether reassuring.

Dr. Schwartz points out that the great preponderance of papers appearing in our orthodontic journals are devoted to the mechanics of treatment, to

appliances and materials. In marked contrast to this, the writings of an earlier day in orthodontics were primarily of the fundamental, biological nature. In the volumes of *"The American Orthodontist,"* published by the Edward H. Angle Society of Orthodontists from 1907-1912, only three of fifty-two articles were devoted to mechanical devices or their manipulation.

A review of those earlier writings reveals quite clearly that the orthodontists of that time were interested in finding out as much as possible about the living organism they were attempting to treat. They sought to develop clear ideas of the normal in order to detect the abnormal. This would place them in a position to recognize what had to be done to correct abnormal conditions. Only then did they attempt to devise means to accomplish correction. Briefly, the emphasis was on "what should be done." How it was done depended upon the ingenuity of each operator.

With the advent of the prefabricated appliance a radical change took place. Given to the orthodontist with the very laudable intention of relieving him of hours of bench work it quickly came to limit him. The machine became the master of the man. Implicit in its adoption was the injunction, "Just follow the directions on the package". It has developed to the point where we even identify orthodontists by the machines they use. This one is an "Edgewise Man", that one a "Labiolingual Man", and the next one an "Universal Man". And many innovations are introduced that consist of more efficient ways of doing things that shouldn't be done in the first place.

I do not believe that the blame for most of this condition can be laid at the door of orthodontics. It is the result of the orientation that the student receives in his dental training and which he brings into orthodontics when he enters it. The undergraduate dental course emphasizes the mechanistic concept almost to the exclusion of sound biological education. In the day of the electron microscope, of tissue culture and all the other marvelous advances in techniques of investigation, the dental student is forced to spend more than half of his time placing one filling after another and making artificial dentures according to the dictates of this articulator or that. Is it any wonder that he is thoroughly indoctrinated with an obsession that "how" he does a thing is more important than "what" he does or "why" he does it.

Turning to the concept that Dr. Schwartz introduces in his paper I can state that I can concur with most of what he says. And perhaps I would agree with all of it were it possible to define certain intangibles with which he deals. It should be apparent from what I have said that I agree wholeheartedly with his thesis that there is too much emphasis on appliances to the neglect of those matters that might hold the answers to our failures.

When we face these matters, we find ourselves confronted with conditions that simply will not yield simple, exact answers. Even that seemingly stable quality, morphology, presents such endless variation that it defies all but the most generalized classification. Yet we attempt to manage it as though we were handling boxes of the same size, shape and weight. And when we attempt to evaluate the more intangible factors such as muscle arrangement, state and function or the degree, rate and time of skeletal growth and all the myriad of other factors with which we must deal, we find that each of these is a variable. Many of them maintain a level only within certain limits — or homeostasis. Actually, aren't we dealing with a complicated problem

of homeostasis? Isn't our major concern the maintaining of an equilibrium of all the forces that hold the teeth in their correct positions?

The factor that comes closest to being fixed is the form of the teeth. They are laid down in their final forms long before they come into function. Aside from the ravages of caries or the wear which their use entails, they are unchangeable. Further than this they have certain configurations which, under proper conditions, permit the precise relations with each other which we call normal occlusion. But the teeth are entirely passive and their positions are completely determined by forces of their environment.

If we pass over the periodontal membrane and alveolar bone, both of which give the teeth the ability to respond, the immediate factor which influences them is the musculature which plays upon them. But this influence is in turn governed by the bony framework to which it is attached. And this in its turn is determined in its form and size by genetics and by growth. Both of these are related through time.

It should never be forgotten that a malocclusion also represents an equilibrium, just as a log jam in a river does. The malocclusion that faces us at the beginning of treatment is frequently our best and perhaps only source of information as to the forces against which we will be contending. The treatment of malocclusion is, in the last analysis, a process of shifting from one equilibrium to another and when we place a mechanical device on the teeth it should be solely for the purpose of influencing their positions toward an equilibrium that is more closely in harmony with the demands of normal function. To force them away from such an equilibrium is to court failure. This is done altogether too frequently when we set for ourselves any other goal than function. Some of our most grievous errors are made when we attempt to establish prematurely, esthetic relations we seek in the adult. All too frequently we employ measures that make a good end result forever unattainable.

Perhaps the concept that has led us farthest astray is occlusal perfection. So strongly has this become ingrained in us that we view a lapped contact as a total failure. To avoid this we extract teeth only to find that we cannot maintain tight contacts. The lapped contact frequently means that our regulating has been a little too early for the growth of the patient. It can either be retained longer or corrected at a later date. But growth will seldom correct an open contact. If given the choice, which would we choose for ourselves?

This then is a plea for the abandonment of treatment based on techniques, the treatment that is concerned only with the "how" of the question. In its place, our major attention should be devoted to the understanding of the contending forces of the "field" that Dr. Schwartz has spoken of. These are the ultimate determinants of success of treatment and their deeper study will pay infinitely greater dividends than an absorbed interest in such matters as gold versus steel or wide versus narrow brackets.

Biologic Variation In Selected Relationships Of Opposing Posterior Teeth*

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In broad anatomic perspective, this paper pertains to nonpathologic variability of the human maxillary and mandibular dental arches considered jointly. It centers on individual differences in spatial and temporal relations among opposing dental units. The segment of ontogeny that is studied begins with the deciduous dentition prior to any oral eruption of permanent teeth and extends to complete replacement of the deciduous dentition with permanent teeth.

OBJECTIVES

The several purposes of the investigation may be grouped under the captions: (1) describing trait distributions, (2) correlating pairs of traits, and (3) studying trait changes ontogenetically. Grouping in this manner, a statement of specific aims is as follows:

1. To describe frequency distributions for:

a. The anteroposterior relation of opposing deciduous second molar teeth at a stage shortly before beginning eruption of permanent first molar teeth.

b. The difference between eruption ages for opposing permanent first molar teeth.

c. The anteroposterior relation of opposing permanent first molar teeth at the time they initially occlude.

2. To present correlation statistics indicating:

a. The association between the anteroposterior relation of opposing deciduous second molar teeth and the anteroposterior relation of opposing permanent first molar teeth.

b. The association between the difference in age of eruption of opposing permanent first molar teeth and the anteroposterior relation of opposing permanent first molar teeth.

3. To investigate longitudinally:

a. The changes for different individuals in the anteroposterior relation of opposing permanent first molar teeth during the first year after they reach occlusal contact and over the period from initial occlusion to the youngest age at which all of the deciduous teeth are replaced by occluding permanent teeth.

b. The changes, during age intervals of three and five years, in the anteroposterior relation of opposing permanent first molar teeth among individuals with the mesiobuccal cusps of these teeth in the same vertical plane at the time of initial occlusion.

SUBJECTS

The subjects were 109 white children, 53 boys and 56 girls, participating in the Facial Growth Study* at the State University of Iowa. Children were enrolled in this program at ages between three and one half and five

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*A longitudinal research program in operation since 1946.

years; the requisites for enlistment were parental willingness to cooperate in a long-term study and likelihood of continuing residence in or near Iowa City.

Each subject accepted for inclusion in the present investigation had on file maxillary and mandibular dental casts satisfying specified criteria at stipulated dental stages. The criteria were as follows:

1. All deciduous molar and canine teeth present on both sides of each dental arch.
2. No casting defects or distortions in the areas of the deciduous second and permanent first molar teeth.
3. No indication of caries affecting the mesial or distal surfaces of teeth in the buccal segments of either dental arch.
4. A dental history showing that the child had not received orthodontic treatment.

The dental stages were:

1. Time at which each of the permanent first molar teeth erupted into the oral cavity.
2. Time at which the opposing permanent first molar teeth on the right and left sides of the dental arches reached occlusion.
3. Two years prior to the time of initial occlusion of the opposing permanent first molar teeth on each side of the arches.

Portions of the total sample were available for study at one or more of four later dental stages. Three of these stages were defined with reference to the time of initial occlusion of opposing permanent first molar teeth; they succeed this event by one year, three years, and five years. The fourth stage was defined as the earliest age when all of the permanent dental units except the third molar teeth had erupted to the occlusal level. For acceptance at any of these stages it was required that a child's dental casts were processed satisfactorily, and that his dental history was negative for orthodontic treatment.

In the aggregate, the sample may be characterized as a group of American-born white children predominantly of northwest European descent and above average in socioeconomic status. Eighty per cent of the subjects were descendants of immigrants from the British Isles, Germany, Scandinavia, or the Netherlands; all except three per cent had at least two grandparents of northwest European ancestry. Information on occupation of the fathers showed that two-thirds of them held professional or managerial positions and the remaining one-third commercial, skilled, or semiskilled positions.

Materials and Methods

The source materials for data collection were hydrocal dental casts made from alginate impressions. Impressions were obtained at semiannual intervals below age twelve years and at annual intervals above this age.

Different methods were used for three tasks: (1) classifying the anteroposterior relation of opposing deciduous second molar teeth, (2) obtaining the difference between eruption ages of opposing permanent first molar teeth, and (3) classifying the anteroposterior relation of opposing permanent first molar teeth.

Method in determining the anteroposterior relation of opposing deciduous second molar teeth: — A procedure was sought whereby the relationship of opposing posterior termini of the deciduous dental arches could be rated by viewing pairs of occluded casts from their buccal aspects.

On dental casts of the mandibular arch it was satisfactory to mark the most posterior point of each deciduous second molar. Always this point fell in

the region of the distobuccal cusp and was visible in a buccal view.

In the maxillary arch, the posterior termini of deciduous second molars lie lingual to the alveolar ridges and are not visible in buccal perspective. Projections buccally were made by placing one edge of a steel rule against both terminal points and drawing a fine line from each point laterally across the alveolar ridge to its buccal side.

It follows that marks were placed on the buccal aspects of the dental casts representing, for the right and left sides separately, (A) the posterior terminus of the maxillary deciduous dental arch and (B) the posterior terminus of the mandibular deciduous dental arch. The casts for a given subject were oriented for rating with the maxillary and mandibular arches in occlusion. Each observed relationship of opposing marks was classified using the following criteria:

I. A anterior to B, or A and B in the same vertical plane.

II. A posterior to B by amounts not exceeding 1.0 mm.

III. A posterior to B by amounts greater than 1.0 mm and not exceeding 2.0 mm.

IV. A posterior to B by more than 2.0 mm.

Two orthodontists served as raters (D.B.C. and E.H.H.*). Each made two independent ratings for each side of every pair of casts. Whenever less than three of the four ratings on a given side were in agreement, an additional rating was made. Sides rated five times and still yielding less than three agreements, were rated twice more. In the original series of four ratings, there were three or more agreements for 80 per cent of the 218 sides examined. For only five per cent of the sides was it necessary to obtain seven ratings.

A specific numerical rating was considered a valid measure of the relation between the posterior termini of opposing second deciduous teeth when it was obtained at least three times in a series of four or five independent ratings or, four times in a series of seven ratings. The data for each side of every pair of accepted casts met one of these criteria.

By the above procedures 218 highly reliable ratings of the anteroposterior relation of opposing second deciduous teeth ($N = 109$ for the right and left sides of the dental arches) were accumulated at a stage shortly before oral eruption of any permanent first molar teeth.

Method in obtaining the difference between eruption ages of opposing permanent first molar teeth: — A tooth was considered erupted when the gingiva was perforated sufficiently to expose an area of tooth enamel approximately one mm in diameter. The time of reaching this stage was approximated from inspection of the series of semiannual casts for each subject.

Two odontologists (H.V.M. and V.B.K.*) estimated the age of eruption of each permanent first molar tooth. Initially, both made independent estimates to the nearest month of age. Whenever their paired records for a given tooth disagreed by two months or more, an additional pair of records was obtained.

For 84 per cent of the 436 teeth, the two initial estimates were either alike or differed by not more than one month. The midpoint of each pair of these estimates was accepted as the age of eruption. On those teeth (16 per

*Grateful acknowledgment is made to Professor Ernest H. Hixon for this service and for additional contributions to the design and execution of the study.

*Grateful acknowledgment is made to Professor Virginia B. Knott for this assistance and for other services during the course of the study.

cent) for which four records were secured, the mean of the tetrad was taken as the age of eruption.

The final procedural step was that of subtracting the eruption age of each maxillary tooth from the eruption age of its antagonist, thereby obtaining values for the difference in age of eruption of opposing permanent first molar teeth.

Method in determining the anteroposterior relation of opposing permanent first molar teeth:— Ratings were made relating a mark on the maxillary dental cast to one of three marks on the mandibular cast. With the aid of a sharp pencil and magnifying glass, short vertical lines visible in a buccal view were drawn to indicate the anteroposterior locations of (C) the tip of the mesiobuccal cusp on the maxillary permanent first molar teeth; and, on the mandibular permanent first molar tooth, (D) the crest of the mesial marginal ridge, (E) the tip of the mesiobuccal cusp, and (F) the buccal groove.

After these sites had been marked, pairs of casts were placed in occlusion and, for the right and left sides separately, classified in one of the following categories:

1. C anterior to D (Angle Class II).
2. C between D and 0.5 mm. anterior to E.
3. C within ±0.5 mm. of E (end-to-end).
4. C between 0.5 mm. posterior to E and 0.5 mm. anterior to F.
5. C within ±0.5 mm. of F (Angle Class I).
6. C more than 0.5 mm. posterior to F.

Classifications were obtained for 550 sides of dental arches representing selected stages between the time opposing permanent first molar teeth reached occlusion and the time twenty-eight permanent teeth were in occlusion. Every side was classified twice by each of two orthodontists (D.B.C. and E.H.H.) working independently. Whenever less than three of the four ratings were in agreement, an additional rating was made. Eighty-nine per cent of the four-record series gave at least three agreements; on extending the series to five, three agreements were obtained in all instances. It follows that each numerical rating utilized for the anteroposterior relation of opposing permanent first molar teeth symbolizes no less than three corresponding records among series of four or five independent appraisals.

Anteroposterior Relation of Opposing Deciduous Second Molar Teeth

Frequency distributions for the anteroposterior relation of the posterior termini of opposing deciduous second molar teeth are presented in Table I. On the total sample of 109 children, frequencies of the different ratings are displayed for the right side of the dental arches and for the left side. Also shown are frequencies on those children (55 of the 109) having the same rating for both sides of the arches. Among the 54 children (50 per cent) having dissimilar ratings on the right and left sides, there were differences of one category for 45 (42 per cent), two categories for 7 (6 per cent), and three categories for 2 (2 per cent).

Further discussion of variation in the relation of occluded deciduous dental arches will center on the following generalization: At the odontic stage shortly before beginning eruption of permanent first molar teeth, the posterior termini of the maxillary dental arch, in relation to corresponding termini of the mandibular arch, are with no greater frequency (1) anterior, or directly above, than (2) posterior by 1.0 mm. or more. For supporting sta-

TABLE I

Anteroposterior relation of the most posterior points of the deciduous dental arches determined two years before the permanent first molar teeth reach occlusion.

Anteroposterior Category	Right Side		Left Side		Both Sides	
	N	%	N	%	N	%
I	9	8	19	17	8	7
II	38	35	31	28	16	15
III	47	43	42	39	25	23
IV	15	14	17	16	6	5

The age distribution for the 109 subjects at this stage extends from 4 years to 6.5 years.

tistics from Table I, note that the relative frequencies from combining categories I and II approximate 44 per cent on each side of the arches and, conversely, those from combining categories III and IV approximate 56 per cent on each side.

The generalization harmonizes with findings from Clinch[3], but is discordant with findings from Baume[1] and Murray[8]. Clinch measured the anteroposterior distance between the terminal points of opposing deciduous second molar teeth on dental casts for 59 children between ages 4.2 and 6.2 years. When these measurements are tabulated in terms of the categories of the present study, 52 per cent fall in categories I or II, and 48 per cent in categories III or IV. The differences between these percentages and those obtained in the present study are not significant statistically (standard error of difference $= 7.4$; $t = 1.1$.).

On dental casts for thirty children between ages four years and six years, Baume studied the anteroposterior relation of the termini of opposing deciduous arches. He reported, without defining the classification categories, that the terminus of the maxillary arch was posterior to that of the mandibular arch in 14 per cent of his subjects. Murray, using *norma lateralis* roentgenograms taken with the dental arches in occlusion on twenty children between ages 5.5 years and 6.5 years, measured along an occlusal line from a perpendicular passing through the lowest point of the left pterygomaxillary fissure to the most posterior points on the maxillary and mandibular deciduous second left molar teeth. The maxillary dimension was found to be surpassed by the mandibular dimension in one subject (5 per cent) only.

The reports of Baume and Murray, based on a total of fifty subjects, lend support to the view that in children around age five years the termini of the deciduous dental arches lie "in the same vertical plane in the majority of cases."[4] Findings from Clinch and the present study, utilizing 168 subjects, draw attention to (1) the wide variation in anteroposterior relation of opposing termini of deciduous arches and (2) the substantial (*ca.* 50 per cent) frequency with which a given terminus of the mandibular arch is anterior by at least 1.0 mm. to that of its maxillary counterpart.

Difference in Eruption Ages of Opposing Permanent First Molar Teeth

As stated previously, difference values were derived by subtracting the age of eruption of each permanent maxillary first molar tooth from the age of eruption of its antagonist. Separate ordered series were compiled for the

TABLE II

Age of oral eruption of the permanent mandibular first molar tooth minus age of oral eruption of the permanent maxillary first molar tooth. Differences expressed in years.

Side of Dental Arches	N	P_5*	P_{25}	Mean	P_{75}	P_{95}
Right	109	—.50	—.16	+.11	+.33	+.66
Left	109	—.42	—.08	+.10	+.34	+.59

* P_5 = fifth percentile, P_{25} = twenty-fifth percentile, etc.

values representing the right and left sides of the dental arches. Table II describes both series statistically. It will be seen:

1. More than 25 per cent of the values for each side of the arches denote earlier eruption in the maxillary arch than in the mandibular arch.

2. Typically, the maxillary permanent first molar tooth erupts slightly (0.1 years) later than the opposing mandibular permanent first molar tooth.

3. More than 25 per cent of the values for each side of the arches show eruption in the mandibular arch to antedate eruption in the maxillary arch by not less than 0.3 years.

The range of individual variation extends from the permanent maxillary first molar tooth erupting 1.3 years before its antagonist to the reverse relation at a magnitude of 2.3 years.

The difference values for the right and left sides of the dental arches were correlated. A Pearson product-moment coefficient of $r = +.69$ was obtained. It is tenable to conclude: (1) there is a statistically significant association between eruption relations of opposing permanent first molar teeth on the two sides of the arches, and (2) the association is positive in direction and of moderate strength.

Anteroposterior Relation of Opposing Permanent First Molar Teeth

Table III presents frequencies for the ratings pertaining to the anteroposterior relation of opposing permanent first molar teeth at the time these teeth reach occlusion. It will be recalled that (1) ratings at this ontogenetic stage were obtained on the total sample of 109 children, and (2) for each subject the buccal segments of both dental arches were intact.

The sections of Table III dealing with the right and left sides of the

TABLE III

Anteroposterior relation of opposing permanent first molar teeth at the time they reach occlusion.

Anteroposterior Category	Right Side		Left Side		Both Sides	
	N	%	N	%	N	%
1	7	6	5	4	2	2
2	12	11	11	10	4	4
3	30	28	22	20	13	12
4	41	38	40	37	23	21
5	18	16	30	28	14	13
6	1	1	1	1	1	1

dental arches separately yield the following findings:

1. The typical relation of opposing permanent first molar teeth at the time of initial occlusion is with the tip of the mesiobuccal cusp of the maxillary tooth somewhat anterior to the buccal groove of the mandibular tooth. More than 35 per cent of the ratings show this relationship (see figures for category 4).

2. Almost 25 per cent of the ratings show the tip of the mesiobuccal cusp of the permanent maxillary first molar tooth falling in or near the same vertical plane as the mesiobuccal cusp tip of the mandibular tooth (see figures for category 3). The mesiobuccal cusp tip of the maxillary tooth, from an additional 20 per cent of the ratings, is indicated to lie in or near the same vertical plane as the buccal groove of the permanent mandibular first molar (see figures for category 5).

3. At the time opposing permanent first molar teeth reach occlusion, the anteroposterior variation of the tip of the mesiobuccal cusp of the maxillary tooth is scattered between a position anterior to the crest of the mesial marginal ridge of the mandibular tooth (5 per cent) and a position posterior to the buccal groove of the mandibular tooth (1 per cent).

The righthand portion of Table III indicates that identical ratings for both sides of the dental arches were obtained on slightly more than one-half of the 109 subjects. Ratings of the two sides differed by one category for forty-one subjects (38 per cent), by two categories for eight subjects (7 per cent), and by three categories for three subjects (3 per cent). The three-category discrepancies included two children with ratings of one and four, and one child with ratings of two and five.

Association Between Anteroposterior Relations of Opposing Deciduous Second Molar and Permanent First Molar Teeth

The coefficient of contingency, C, is an appropriate statistic[5] for determining the strength of association between the anteroposterior relation of opposing deciduous second molar teeth at a stage shortly before eruption of permanent first molar teeth (variable X) and the anteroposterior relation of opposing permanent first molar teeth at the time they reach occlusion (variable Y). In applying this correlation procedure, it was necessary to combine some of the rating categories so that every theoretical cell frequency would be 5 or higher.

For the left side of the dental arches, C was computed using the four categories of opposing deciduous second molar teeth and collapsing the six categories of opposing permanent first molar teeth as follows: 1-3, 4, 5-6. The coefficient of contingency derived from this 4 x 3 table is $C = +.47$. A moderate positive relationship is indicated. On the one hand, the hypothesis of zero correlation in the population may be rejected, since the value secured for Chi square (31.2) is statistically significant ($P = 0.01$ when, with 6 *df*, Chi square is not less than 16.8). On the other hand, the maximum value attainable from a 4 x 3 table is $C = .93$. It is a reasonable interpretation that the obtained $C = +.47$ symbolizes a positive association of moderate strength.

On the right side of the dental arches, the required minimum for each theoretical cell frequency was met by a 2 x 4 table. This table was formed by the following: deciduous second molar categories I-II and III-IV; permanent first molar categories 1-2, 3, 4, 5-6. The obtained statistics are $C = +.47$ and Chi square $= 31.6$. With 3 *df*,

P = 0.01 when Chi square is not less than 11.3; the maximum value attainable from a 2 x 4 table is C = .91. As before, the finding of a direct moderate relationship is tenable.

An analysis was done for the left side of the dental arches using the same 2 x 4 contingency-table construction as was employed for the right side. The statistics from this comparable treatment are C = +.42 and Chi square = 23.3.

It follows that the initial occlusal relation of opposing permanent first molar teeth is not determined *solely* by the anteroposterior relation of the posterior termini of opposing deciduous second molar teeth.

Of the several facets of the above finding that could be specified, one has particular relevance in orthodontic diagnosis. At the stage prior to eruption of permanent first molar teeth, there are twenty-eight sides of occluded deciduous dental arches for which the posterior terminus of the maxillary arch is either anterior to the posterior terminus of the mandibular arch or in the same vertical plane as the posterior terminus of the mandibular arch (see Table I, category I). After the opposing permanent first molar teeth have erupted to occlusal contact, 20 (71 per cent) of the 28 sides fall in categories 1 or 2, *i.e.*, the tip of the mesiobuccal cusp of the maxillary permanent first molar tooth lies anterior to the mesiobuccal cusp of the mandibular permanent first molar tooth by 0.5 mm. or more. From reference to Table III, note that this subgroup includes less than 60 per cent of the total number of sides placed in categories 1 and 2.* Clearly, in the orthodontic examination of five-year-old children, it would be unsound to assume that whenever posterior termini of opposing deciduous arches lie in the same vertical plane this forbodes an Angle Class II relation of opposing permanent first molar teeth.

*The specific placements are nine in category 1 (75 per cent of the Table III total for category 1) and eleven in category 2 (48 per cent of the Table III total for category 2).

Association Between Order of Eruption and Anteroposterior Relation of Opposing Permanent First Molar Teeth

To what extent is there concomitant variation of the differences in eruption age of opposing permanent first molar teeth and the anteroposterior relations of these teeth at the time of initial occlusion? This question was studied by means of the same correlation method as was used in the previous section.

For each side of the dental arches, a 3 x 3 contingency table was found satisfactory. Differences between the eruption ages of opposing permanent first molar teeth were tabulated in the following categories: maxillary tooth erupting earlier than mandibular tooth by 0.15 years or more; maxillary tooth erupting less than 0.15 years before, at the same time, or less than 0.20 years after the mandibular tooth; and maxillary tooth erupting later than the mandibular tooth by 0.20 years or more. Ratings for anteroposterior relation of opposing permanent first molar teeth at the stage of initial occlusion were grouped as follows: 1-2, 3, 4-6.

The statistics obtained are C = +.36 and Chi square = 16.3 for the right side of the dental arches and, for the left side, C = +.41 and Chi square = 21.5. With 4 *df*, P = 0.01 when Chi square is not less than 13.3. It follows that both coefficients of contingency represent a positive relationship of low-moderate strength.

In a study utilizing dental casts secured on sixty children "before and

after the eruption of the permanent first molars," Baume[2] reported that in those children showing "Angle Class II malocclusion after eruption . . . the upper permanent first molar always erupted before the lower one." Comparable data from the present investigation are as follows: Of the 35 sides of the dental arches placed in categories 1 and 2 with respect to the anteroposterior relation of opposing permanent first molar teeth (Angle Class II malocclusion), 80 per cent show eruption of the maxillary tooth earlier than the mandibular tooth by periods varying from 2 weeks to 15 months, and 20 per cent show eruption of the two opposing teeth at the same time or eruption of the maxillary tooth later than its antagonist by intervals varying from 2 weeks to 3 months.

Lo and Moyers[6] have reported: "In cases of Class II molar relationship there is a strong tendency for the maxillary molars to erupt prior to their mandibular counterparts." The data of the present study confirm this generalization at two odontic stages: when opposing permanent first molar teeth attain occlusal contact, and one year later. At each stage, the maxillary tooth is found to erupt before the mandibular tooth in 80 per cent of the Class II group, *i.e.*, the group for categories 1 and 2 combined.

The probability that Class II malocclusion is *preceded* by eruption of the maxillary permanent first molar tooth ahead of its antagonist should not be regarded as equivalent to the probability that earlier eruption of the maxillary tooth is *followed by* Class II malocclusion (distoclusion). Among the seventy-five sides of the dental arches for which the permanent maxillary first molar tooth erupted before its opposing mandibular tooth, the ratings for anteroposterior relation on reaching occlusion are distributed as follows: 37 per cent in categories 1 and 2, 31 per cent in category 3, and 32 per cent in categories 4 and 5. These findings give scant support to the view that "arrival of the maxillary first molar ahead of the mandibular first molar . . . is symptomatic of developing distoclusion."[7]

How efficiently is it possible to predict Class II malocclusion of opposing permanent first molar teeth from joint utilization of the anteroposterior relation of posterior termini of opposing deciduous second molar teeth, and the difference between eruption ages of opposing permanent first molar teeth? Information on this question was secured by employing the following twofold scheme: (1) classification in category I with respect to the anteroposterior relation of the most posterior points of the deciduous dental arches prior to eruption of permanent first molar teeth, and (2) eruption of the permanent maxillary first molar tooth 0.5 years or more before eruption of its antagonist.

Ten sides of the dental arches (five for each sex) are found to meet both of these prescriptions. All ten register a Class II relation of opposing permanent first molar teeth on initial occlusion.* Nevertheless, there are twenty-five sides of the dental arches which remain unselected by the predictive scheme and have a Class II relation of the permanent first molar teeth when these teeth erupt to occlusion (see figures for categories 1 and 2, right and left sides, in Table III). It follows that, although the scheme has some forecasting value, it predicts no more than one-third of the Class II relations

*Class II predictions below 100 per cent correct are obtained from the use of any larger portion of the distribution for (1) anteroposterior relation of opposing deciduous dental arches or (2) difference in eruption ages of opposing permanent first molar teeth.

with which the clinician will be confronted.

Change with Age in Anteroposterior Relation of Opposing Permanent First Molar Teeth

Beginning with the stage of initial occlusion of opposing permanent first molar teeth, it was possible to study 89 subjects (44 girls and 45 boys) over a one-year period, and 48 subjects (23 girls and 25 boys) over the interval ending when all of the permanent teeth except the third molars had erupted to the occlusal level. For these subjects, dental casts were available with all of the posterior deciduous teeth present at two stages, and their permanent successors all present at the third stage.

Findings for the first year after initial occlusion of opposing right and left permanent first molar teeth are as follows:

1. Of the 178 sides of the occluded dental arches, each rated independently at the two stages, 62 per cent show no change.

2. There are one-category changes for 35 per cent of the paired ratings representing the beginning and end of the year. These changes occur about equally in both directions: the specific relative frequencies are 49 per cent in one direction and 51 per cent in the other.

3. Three per cent of the 178 sides of occluded dental arches, each rated at the two stages one year apart, change more than one category. Included here are three shifts in one direction and two in the other. More explicitly, there are two unilateral shifts from category 2 to category 4, a unilateral shift from category 1 to category 3 and a bilateral shift from category 5 to category 3.

Longitudinal study of changes in the anteroposterior relation of opposing permanent first molar teeth over the period from initial occlusion to the stage when all of the deciduous teeth have been replaced by occluding permanent teeth gives the following findings:

1. Of the ninety-six sides of occluded dental arches, each rated independently at the two stages, 19 per cent show no change.

2. Eight per cent of the sides shift to a lower numbered category. None of these shifts exceeds one category.

3. Seventy-three per cent of the sides change to a higher numbered category. Comprising this 73 per cent, there are 47 one-category changes, 20 two-category changes, and 3 changes of more than two categories. The two-category shifts are largely from category 3 ("end-to-end") to category 5 (Angle Class I), or from category 4 to category 6 (tip of mesiobuccal cusp of maxillary tooth more than 0.5 mm. posterior to buccal groove of opposing mandibular tooth). Two of the larger shifts are from category 3 to category 6. The maximum shift is from category 2 (mesiobuccal cusp tip of maxillary tooth between mesiobuccal cusp tip and anterior marginal ridge of mandibular tooth) to category 6.

4. There are four instances of change exceeding one category on *both sides* of the dental arches. One child changes from category 3 to category 5 on both sides, another child from category 4 to category 6 on both sides, another from categories 1 to 3 on one side and 2 to 4 on the other, and another from categories 3 to 5 on one side and 3 to 6 on the other. All of these shifts depict the mandibular permanent first molar tooth moving anteriorly with age in its relation to the maxillary permanent first molar tooth.

Serial Study of Children with Cusp-to-Cusp Relation of Opposing Permanent First Molar Teeth at Initial Occlusion

Thirteen subjects were rated 3 (end-

to-end) bilaterally when the opposing permanent first molar teeth reached occlusion (see Table III). It was possible to study most of these subjects longitudinally, dental casts being available for twelve of them (six of each sex) at initial occlusion and three years later, and for eight of them at initial occlusion and five years later. For both postocclusal stages, dental casts were accepted regardless of the number or assortment of teeth present anterior to the permanent first molar teeth.

Three years after initial occlusion (N = 12):

1. Five children (42 per cent) show no anteroposterior shift on either side of the dental arches, *i.e.*, at both stages the tips of the mesiobuccal cusp of the right and left maxillary teeth are approximately in the same vertical plane as the tips of the corresponding cusps of the mandibular teeth.

2. Seven children (58 per cent) change from category 3 to category 4 on at least one side of the dental arches. This shift toward Class I permanent first molar relationship is found on both sides of the arches for three children. For the remaining members of this subgroup, one side of the arches shows no change in one child, change from category 3 to category 6 in one child, and change from category 3 to category 2 in two children.

Five years after initial occlusion (N = 8):

1. Six children (75 per cent) register a change on each side of the dental arches from category 3 to categories 4 or 5. For three children, the change is to category 4 bilaterally; for two children, it is to category 4 on one side and category 5 (Class I) on the other, and for one child, it is to category 5 bilaterally.

2. Two children (25 per cent) show change on one or both sides of the dental arches from category 3 to category 2 (Class II). For one child, there is no change on one side and a shift to category 2 on the other; for the other child, both sides shift from category 3 to category 2.

The findings of this section indicate that among children whose maxillary and mandibular permanent first molar teeth initially occlude with the tips of the mesiobuccal cusps in the same vertical plane, there is usually a definite, although slight, change in anteroposterior relation with age. Over the first triennium following attainment of the cusp-to-cusp (end-to-end) relation none of the twelve subjects manifests a change of more than one category bilaterally. Extending the postocclusal period to a quinquennium, one only of the eight children accessible for study shows a two-category change bilaterally. The predominant finding is a one-category shift on one or both sides of the dental arches from the opposing mesiobuccal cusp-to-cusp relation toward the Class I relation.

Summary

This study pertains to the variation and correlation of three odontic traits in orthodontically untreated white children. Each trait represents a temporal or spatial relation between two posterior teeth. Opposing deciduous second molar teeth are studied at a stage before the eruption of permanent first molar teeth, and opposing permanent first molar teeth at several stages from their oral eruption to the time all of the deciduous teeth are replaced by permanent teeth.

The data were obtained from hydrocal dental casts accumulated in a long-term research program. Every child accepted as a subject for the study was required to have all deciduous molar and canine teeth present when the permanent first molar teeth reached the occlusal level. The sample com-

prises 109 American-born white children predominantly of northwest European descent and above average socioeconomic status.

Findings are presented on the following topics: (1) variation in the anteroposterior relation of opposing deciduous second molar teeth prior to eruption of the permanent first molar teeth, (2) variation in the sequence of eruption of opposing permanent first molar teeth, (3) variation in the anteroposterior relation of opposing permanent first molar teeth at the time they initially occlude, (4) correlation of the anteroposterior relations of opposing deciduous second molar teeth and permanent first molar teeth, (5) association between the sequence of eruption of opposing permanent first molar teeth and the anteroposterior relation of opposing permanent first molar teeth, and (6) change with age in the anteroposterior relation of opposing permanent first molar teeth, including (7) special study of children showing mesiobuccal cusp-to-cusp relation of these teeth at initial occlusion.

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The Sectional Arch In Class II Extraction Cases

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I have long questioned the practice of a complete abandonment of the sectional arch in the treatment of Class II extraction cases. I have continued to use the sectional arch in the preliminary stages of the full band technique. The sectional arch is employed in a form somewhat modified from the usual type. It is my belief that the use of this modified sectional arch provides advantages which are both substantial and measurable, advantages to the patient as well as to the operator.

The complete band technique in the treatment of malocclusions is an exacting and time consuming undertaking. Of course, if it can be started gradually, it will be easier for the patient and the operator, too. It also can be made less overwhelming to the patient to have only the cheek teeth banded first; later, the lower incisors, and finally, the maxillary incisors as treatment progresses.

The object of the modified sectional arch is to apply force *only* in the direction in which the teeth are to be moved. This method of approach avoids the placing of bands on the upper anterior teeth and the necessity for a painstaking application of a full maxillary archwire in the early stages of treatment.

This modified type of sectional arch is quite simple to construct and simple to use. The usual type of sectional arch requires several replacements during the treatment period. By use of the clock spring (as evolved and designed by Dr. Strang) the effective life is extended many times and breakage is virtually nonexistent. Its functional durability is achieved by the simple act of activating the clock spring with a new ligature. As the tie loop is always against the tube on the molar band, there is not the "see-saw" action on the anchor tooth that obtains when a loop sectional arch is employed.

There seems to be no question about the fact that the change in the occlusal relations of the maxillary and mandibular buccal teeth is a reciprocal "fifty-fifty" movement. It consists of a forward migration of the mandibular molars and premolars and a distal movement of the maxillary side teeth to obtain the change in the mesiodistal relation and to close the spaces.

The strategy of treatment is to have intermaxillary force constantly available before exerting a distal moving force to the maxillary canines. (It is assumed that the elastics will be worn continually as instructed.) This permits a long horizontal resilient pull of the intermaxillary elastics as the hook is fashioned in the mesial end of the sectional arch. The usual sectional arch, with the intermaxillary hook attached distally to the closing loop, affords a shorter and more vertical pull. My experience with the modified sectional arch has convinced me that the long horizontal pull which it affords is more desirable.

As a prerequisite to the use of this sectional arch, it is necessary that the following band placement and arch manipulation be executed.

Appliance and band placement begins on the mandibular teeth and an

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.021 x .025 loop arch is applied just as soon as it is practical and possible to do so. The molars and second premolars are banded first, preferably before extraction, and the canines immediately afterward. It is good procedure to place archwires and bands promptly after extraction in order to control the space closure. This procedure will avoid unfavorable tipping of the teeth following extraction, tipping which may take place if there is postextraction delay for any one of a variety of reasons, such as illness or failure to keep appointments.

The first mandibular archwire employed is an .018 with a coil spring between the canine brackets. The coil spring is .010 hard steel, compressed about 1½ times the width of a single bracket. In the event that the occlusal discrepancy is so great as to require adjustment in the occlusal plane, a corresponding "step-up" is made in the canine area to permit easy seating of the archwire into the brackets. The archwire is not made passive in the occlusal plane since some depressive action should be exerted. If, after a few weeks, spaces do not develop between the incisors, the coil spring may be opened slightly. Any occlusal interference from the maxillary first premolars should be constantly observed; if such interference occurs, its removal should be accomplished in the usual manner by extraction of the maxillary first premolar or by the insertion of a bite plane.

When slight spacing occurs between the lower incisors, they can be easily banded. Next, a series of round archwires is employed until a loop arch of .021 x .025 steel can be inserted.

Concurrently with this procedure on the mandibular teeth, the maxillary buccal teeth have been banded and levelled following the extraction of the maxillary first premolars. Full round arches may be used followed by laminated sectional arches, if necessary, to complete the levelling.

Finally, the working sectional arch is applied. This wire is made of .019 x .026 steel with a tie loop against the molar tube and a hook in the mesial end, forward of the canine, for intermaxillary elastics. The tie loop is in contact with the mesial end of the tube on the molar band so that the force of the intermaxillary elastics will be directly transmitted to that particular tooth. After several weeks' application of the elastics, clock springs are added. The clock springs are made of .022 gold and platinum wire. The attachment to the sectional arch is made with low fusing stainless steel solder at a point approximately midway between the premolar and canine brackets. The end to be soldered is bent into a small hook in the notched beak of an SSW 342 plier; the solder is fused to the hook in the gold wire which is applied to the buccal and occlusal aspect of the section archwire and is drawn to the steel wire the very moment the solder is molten. The soldering procedure is one which I have employed over a period of years and it has, for me, proved most effective. It is a method which rarely fails to achieve the ideal result of a complete encirclement of the steel wire by the solder, a goal I was never able to reach with any pronounced assurance by other soldering procedures. The buccal placement offsets the coil and the second loop of the spring will be above the sectional archwire. Usually this is enough to clear the gingival tissue.

The clock springs are fashioned by bending the gold wire around the beaks of a tapered round-nosed plier to form a coil two to three millimeters in diameter (Fig. 1).

That a coil, seemingly so small, proves fully effective should not be

Fig. 1. An artist's sketch of a sectional archwire and clock spring. The incisors would not be banded at this stage.

surprising when one considers the fact that such a coil requires a very substantial length of wire. Among its many advantages is the fact that it provides a light resilient force and thus avoids the problems that may ensue from excessive force. Coils of clock springs larger than three millimeters in diameter are more difficult to adjust to avoid impinging on the soft tissue and may well reduce the distance the canine bracket can move along the sectional archwire.

The terminal end of the clock spring is bent around the end of an SSW 342 plier to form a small eyelet. The cut end is finished with a safe-sided disk. This will allow close contact in completing the eyelet with the plier mentioned above.

The clock spring is activated by ligating to the distal staple of the canine band, making one twist to hold the compression of the spring; then one end of the ligature is passed lingually to the sectional archwire and through the gingival wing of the canine bracket. It then passes buccally to the sectional wire to seat it in the bracket. The purpose of doing the ligature in this way is to avoid loose, floppy ends with their attendant propensity to irritate the lips.

The canines may thus be moved into contact with the second premolars, or within a millimeter or two, before banding the maxillary incisors.

The stage is now set for the banding of the incisors which, under the methods here outlined, have a minimal period of banding. Usually the labially inclined incisors can be retracted with round arches and space-closing rectangular arches in the bracket slots. In the event that the labial inclination is severe, and "toe-hold" difficult to overcome, then the lateral and central sections of the rectangular archwire are applied incisally to the incisor bracket wings. This permits depression and tipping of the incisors without strain upon the maxillary anchorage. Placing the archwire below the wings of the brackets rather than in the slots avoids any binding action and the necessity of a detorquing adjustment in the incisal segment of the wire. After the incisors are uprighted, or nearly so, the anterior section of new finishing archwire is fitted into the slots of the brackets on those teeth.

Some reference should be made to one of the presumed advantages of *immediate* full banding, namely, the utilization of the resistance value of the maxillary anterior teeth. Such resistance value as may exist is admittedly not brought to bear in the sectional arch technique. It is my opinion that the advantages gained by the use of the sectional arch, as modified, so completely outstrips any benefits claimed for harnessing the maxillary incisors that, consequently, I am devoted to the sectional arch. Figure 2 illustrates a case treated by this procedure.

To sum up, the advantages of the modified sectional arch in the early stages of treatment of a Class II extraction case are in the main as follows:

1. Expeditious correction of the Class II relation.
2. Simplification of archwire manipulation.
3. Minimal time of banding the maxillary incisors.
4. Avoidance of adverse force to the

Fig. 2. Treatment of a boy aged thirteen years. Left, February 1957. Middle, April 1958 at the end of sectional arch treatment. Right, April 1959, the end of active treatment. Intermaxillary elastics were worn for five months.

maxillary incisors.

5. Minimal patient discomfort in band placement.

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